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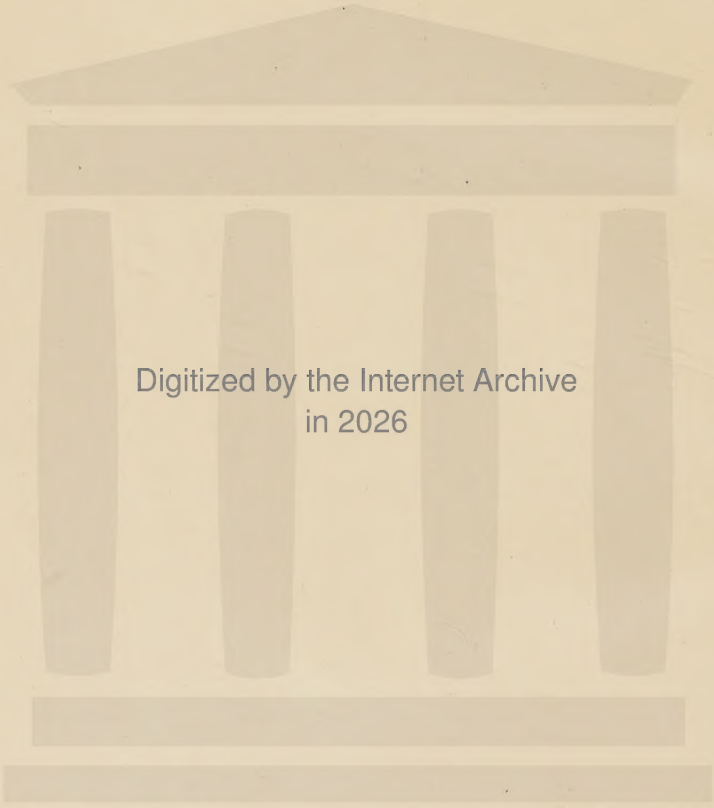

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SYLLABUS

OF

A COURSE OF LECTURES

ON

ECONOMIC GEOLOGY

BY

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IN LELAND STANFORD JUNIOR UNIVERSITY

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PREFACE.

This syllabus is intended for the use of students both while in college and afterwards. The outlines given can be expanded by notes taken from the lectures, from reading, and from observation, and written out on the opposite pages left blank for that purpose.

One of the most important things a student of economic geology needs to learn is where to find and how to use information that has been published. I have, therefore, endeavored to give references: first, to the works on the general subject of economic geology; second, to periodicals in which articles are to be looked for upon various economic subjects; third, to papers and reports upon special subjects.

The general works and periodicals are listed on pages IV and VI, and the references to special topics are given as footnotes in the body of the syllabus under each topic. The list of references is not complete in any case, but it is usually sufficient to put the student in the way of finding other titles.

By posting titles in the syllabus as the articles appear the student can add greatly to its usefulness, and in this way keep his own copy up to date.

More space is given to the economic geology of the United States than to that of foreign countries. Some of the subjects are necessarily but briefly treated.

For the sake of uniformity, the tons mentioned in this syllabus have all been reduced to short tons of 2,000 pounds.

The compositions of minerals, unless otherwise stated, are the theoretic ones, and are taken from Dana's System of Mineralogy.

The charts showing the production, imports, and prices, were made chiefly from the data of the United States Geological Survey. Space has been left on the right side of these diagrams so that the lines can be continued for several years.

A few blank pages are left at the back of the book for the addition of notes and memoranda on special subjects not treated in the syllabus.

The first two editions of this syllabus were prepared with the help of Professor J. F. Newsom. Though he is not responsible for this third edition, I have had his cordial coöperation in its preparation.

JOHN C. BRANNER.

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GENERAL WORKS ON ECONOMIC GEOLOGY.

Books and articles upon special subjects are mentioned under each topic in the body of the syllabus.

J. D. Whitney.—The metallic wealth of the United States. Philadelphia, 1854; 510 pages. Scarce.

B. von Cotta.—A treatise on ore deposits. Translated from the German by F. Prime, Jr. New York, 1870; 575 pages. Scarce.

David Page.—Economic geology. London, 1874; 336 pages.

Albert Williams, Jr.—Popular fallacies regarding precious metal ore deposits. Fourth ann. rep. U. S. Geological Survey, 257-271. Washington, 1884.

S. G. Williams.—Applied geology. New York, 1886; 386 pages.

E. Fuchs et L. de Launay.—Traité des gîtes minéraux et métallifères. 2 vols. Paris, 1893. (Contains many valuable references.)

George Moreau.—Etude industrielle des gîtes métallifères. Paris, 1894; 453 pages.

R. S. Tarr.—Economic geology of the United States. New York, 1894; 509 pages.

J. F. Kemp.—The ore deposits of the United States. Fourth edition, New York, 1901; 484 pages.

F. Posepny.—The genesis of ore deposits. Transactions of the American Institute of Mining Engineers, 1893, XXIII, 197-369; also a separate publication of the Institute. New York, 1895.

J. A. Phillips and Henry Louis.—A treatise on ore deposits. London, 1884; 651 pages. Second edition rewritten, etc. By Henry Louis, London, 1896; 943 pages.

L. de Launay.—Contribution a l'étude des gîtes métallifères. Ann. des Mines. 9me sér. XII, 119-228. Paris, 1897.

G. P. Merrill.—The non-metallic minerals; their occurrence and uses. XI, 414. New York, 1904.

A. W. Stelzner.—Die Erzlagerstätten. Leipzig, 1904.

J. E. Spurr.—Geology applied to mining. 8°, ill. XIV, 326. New York, 1904.

R. Beck.—The nature of ore deposits. Translated by W. H. Weed, 2 vols. New York, 1905.

James Park.—A text-book of mining geology. IX+219. Philadelphia, 1906.

A. Ries.—Economic geology. New York, 1910.

Mineral Statistics.

The Mineral Resources of the United States. Published annually since 1883 by the U. S. Geological Survey. From 1893 to 1900 these reports were included in the annual reports of the Director of the Survey.

The Mineral Industry. Edited by R. P. Rothwell and published at New York annually from 1893 to 1900. Prior to 1893 the Engineering and Mining Journal published annually statistics of the mineral industries of the United States. From 1901 to date by various editors.

The Director of the Mint publishes an annual report upon the production of the precious metals in the United States.

The census reports, published every ten years by the U. S. Government.

PERIODICAL PUBLICATIONS

containing articles on economic geology.

1. Annales des Mines. Published at Paris since 1794.
2. American Journal of Science. Published monthly at New Haven, Conn., since 1819.
3. Bulletin de la Société Géologique de France. Paris, France; one volume annually since 1830.
4. Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Stuttgart, annually since 1830.
5. Berg und Hüttenmännische Zeitung. Leipzig since 1842.
6. Quarterly Journal of the Geological Society of London. One volume annually since 1845.
7. Geological Magazine. Begun in 1858 as The Geologist; continued since 1865 as The Geological Magazine. Published monthly at London, England.
8. The Mining Journal (weekly). London since 1834.
9. Engineering and Mining Journal. Published weekly at New York since 1866.
10. Mining and Scientific Press, San Francisco, Cal. Weekly since 1860.
11. Transactions of the American Institute of Mining Engineers. New York; one volume annually since 1870.
12. School of Mines Quarterly. Published quarterly at New York since 1879.
13. Technology Quarterly. Published quarterly by the Massachusetts Institute of Technology, Boston, from January, 1887, to June, 1908, when it was suspended.
14. American Geologist. Published monthly at Minneapolis, Minn., from January, 1888, until December, 1905, when it was merged into Economic Geology.
15. Bulletin of the Geological Society of America. One volume annually since 1890.
16. Transactions of the Institution of Mining and Metallurgy. London, since 1891.
17. Journal of Geology. Published semi-quarterly at the University of Chicago since 1893.
18. Zeitschrift für Praktische Geologie. Berlin, Germany, since 1893.
19. Annales des Mines de Belgique. Brussels, since 1896.
20. Monographs, bulletins and annual reports of the United States Geological Survey, Washington, since 1880.
21. Geologisches Centralblatt. Berlin, Germany, since January 1, 1901.
22. Economic Geology. Semi-quarterly since October-November, 1905.

REFERENCES TO WORKS.
ON MINING LAW

[1]Curtis H. Lindley.—A treatise on the American law relating to mines and mineral lands. 2 vols. 2d ed. San Francisco, 1903.

[2]D. M. Barringer and J. S. Adams.—The law of mines and mining in the United States. Boston, 1897.

[3]E. P. Clark.—Mining law. School of Mines Quarterly, V, 242-258. New York, 1884.

[4]R. W. Raymond.—Historical sketch of mining law. Mineral Resources of the United States, 1883-84. 988-1004. Washington, 1885.

[5]R. W. Raymond.—The law of the apex. Trans. Amer. Inst. Min. Eng., XII, 387-444, 677-688. New York, 1884.

[6]Mining laws. Tenth Census, XIV. Washington, 1885.

[7]A. H. Ricketts.—Dissertation upon American mining law. Eleventh ann. rep. of the State Mineralogist (of California), 1891-92, 521-574. Sacramento, 1893.

[8]Henry N. Copp.—American mining code.

[9]W. D. McPherson and J. M. Clark.—The law of mines in Canada. Toronto, 1898.

[10]Mining code of the Mexican Republic. Second ed. Mexico, 1893.

[11]Ley minera y ley de imposto á la mineria con sus respectivos reglamentos. Mexico, 1894.

[12]R. E. Chism.—A synopsis of the mining laws of Mexico. Trans. Amer. Inst. Min. Eng., XXXI, 3-54. New York, 1902.

[13]Abstracts of current mining decisions. School of Mines Quarterly, XXIII, 374. New York, 1902.

[14]C. H. Shamel.—The American law relating to minerals. School of Mines Quarterly, XXVII, 1-27. New York, 1905.

[15]G. W. Riter.—Weak points in the federal law in relation to mineral lands. Engineering and Mining Journal, LXXXIII, 184-185. New York, 1907.

[16]A. H. Ricketts.—Short talks on mining law. Engineering and Mining Journal, LXXXVI, 81, 117, 168, 212, 281, 363, etc. New York, 1908.

Subdivisions of the Geological Column, or Order of the Stratified Formations of North America.

Characteristic life	Period	System[1]		Series[1]
Man	Psychozoic			
Mammals	Cenozoic or Kainozoic	Quaternary		Recent Pleistocene
		Tertiary		Pliocene Miocene Oligocene Eocene
Reptiles	Mesozoic	Cretaceous		Upper Lower
		Jurassic		Upper Middle Lower
		Triassic		Upper Middle Lower
Acrogens Amphibians	Paleozoic	Carboniferous		Permian
				Coal Measures or Pennsylvanian
				Lower Carboniferous or Mississippian
Fishes		Devonian		Catskill Chemung Hamilton Corniferous Oriskany Lower Helderberg
Invertebrates		Silurian	Silurian or Upper Silurian	Salina Niagara
			Ordovician or Lower Silurian	Trenton Canadian
		Cambrian		Potsdam Acadian Georgian
	Eozoic	Algonkian		Keweenawan Huronian
	Azoic	Archean		Keewatin Laurentian

[1]G. K. Gilbert. American Geologist, XXXIII, 141. Minneapolis, 1904.

Part I

The Nature, Origin, Forms, Etc. of Economic Geologic Deposits

ECONOMIC GEOLOGY.

Introductory.

What is meant by economic geology; geology in its relations to arts and industries.

Necessity of understanding pure geology before attempting to apply it.

Geological products are used, directly or indirectly, in every branch of human industry. The importance and prosperity of a nation depend largely upon its geological products.

Geology in its relations to agriculture.[1]

Soils are geological products.

The soil belts of Tennessee, Kentucky, Indiana, Missouri are residual soils, varying with the rocks from which they are derived.

Soils transported by water, by ice and by wind; the drift area of the United States.

Fertilizers.

Green-sand marls of New Jersey.

Apatite deposits of Canada.

Phosphates of South Carolina, Florida, Tennessee, and Arkansas.

Land-plaster, or gypsum, of New York, Michigan, etc.

Kainit from Stassfurt, Germany.

Geology and forests.[2]

Geology and manufacturing industries.

The great industries of nations and states are often determined by local geology. Cities and towns have often had their locations determined by the proximity to some mineral or mineral-bearing formation; others owe their importance to such proximity.

Relations of England's wealth and power to the mineral resources of that country.

The wealth and power of the United States have increased in proportion to the development of the country's mineral resources.

[1]J. E. Marr.—Agricultural geology. XI, 318. London, 1903.

A. Lonay.—L'agronométrie specialement dans ses rapports avec la géologie. Bul. Soc. Belge de Géologie. XVI, 40-46. Bruxelles, 1902.

[2]A. Hollick.—The relation between forestry and geology in New Jersey. American Naturalist, XXXIII, 1-14; 109-116, 1899.

Note the commercial importance of various states, and how each owes its importance to some geological product, omitting purely mining and purely manufacturing states:

Alabama: iron, coal.

California: gold, quicksilver, petroleum.

Indiana: natural gas, building stone, glass, coal.

Maine: granite.

Michigan: copper, iron ore.

Missouri: zinc, lead, iron ore, glass-sands, fire-clays.

New Jersey: marls, clays, zinc.

Ohio: coal, building stone, natural gas, petroleum.

Pennsylvania: iron, coal, petroleum.

Geology and art.[3]

The local beginnings of ceramic art were made possible by the existence of available clays. The great art manufacturing industries of Staffordshire, England, and of Limoges, France, sprang up in those places partly because of the presence or proximity of the necessary clays.

The influence of the clays of New Jersey and Ohio upon the pottery industries.

Influence of Parian and Carrara marbles on sculpture.

How the geology of Holland has affected the landscape paintings of that country.

Influence of building stones and brick-clays on architecture. Examples are the brownstones of New Jersey and Connecticut; the limestones of Montreal; the brick-clays of Philadelphia, St. Louis, and Milwaukee.

Geology in relation to engineering.[4]

Geology and roads.

Character of roads affected by local geology or by the presence or absence of good road-making materials.

Limestone "road-metal" of Southern France.

Drift gravels of the glaciated portion of the United States. The jaspers of San Francisco and the Coast Ranges; the cherts of southwestern Missouri; the auriferous gravels of the Sacramento Valley.

Geology and railways.

The location of railways is often determined by the presence of minerals that promise business.

Geologists employed by railways.

Geology and migration.

[3]Hugh Miller.—Landscape geology. Trans. Edin. Geol. Soc., 1892, VI, pt. III, 129. Also London, 1891.

J. E. Marr.—The scientific study of scenery. London, 1900.

C. D'Orbigny et A. Gente.—Géologie appliquée aux arts et à l'agriculture. 8°335 pp. Paris, 1851.

[4]E. Niviot.—Géologie appliquée a l'art de l'enginieur. 2 vols. Paris, 1887-1889.

THE CONSTRUCTION OF MAPS AND SECTIONS FOR GEOLOGIC PURPOSES.

When a geological deposit or formation has economic value, its precise location and distribution become important; these can be shown by maps and sections.

Advantages of maps over verbal descriptions.

Maps may show horizontal location alone, or both horizontal and vertical position.

Importance of instrumental work.[1]

Horizontal location determining ownership, extent, and value.

How maps are made.[2]

Regional maps; local maps.

Every geologic map is based upon some kind of topographic map, and if a topographic map is not available one must be made.

Knowledge of map-making indispensable to geologists.

Triangulation.

By U. S. Coast and Geodetic Survey; U. S. Engineers; U. S. Geological Survey; Lake Survey; special surveys.

Chaining: tacheometer, telemeter or stadia measurements.[3]

Plane-table surveying.[4]

Importance and advantages of finishing the map on the ground when possible.

Photo-topography.[5]

[1]B. S. Lyman.—Need of instrumental surveying in practical geology. Transactions American Institute of Mining Engineers, XL, 636-643. New York, 1910.

[2]Archibald Geikie.—Outlines of field-geology. London and New York, 4th ed., 1891.

Henry Gannett.—A manual of topographic methods. Monograph XXII, U. S. Geological Survey. Washington, 1893.

Henry Gannett.—The aims and methods of cartography. Maryland Geological Survey, II, pt. III, 245-335. Baltimore, 1898.

C. W. Hayes.—Handbook for field geologists. New York, 1909.

[3]R. H. Richards.—A new prismatic stadia. Jour. Assoc. of Eng. Socs., XIII. 1894.

J. B. Johnson.—Topographical surveying by means of transit and stadia New York, 1885.

A. Winslow.—The theory of stadia measurements, accompanied by tables of horizontal distances and differences of level for the reduction of stadia field observations. First report of progress in the anthracite coal region. Second Geological Survey of Pennsylvania, AA, 325-344. Harrisburg, 1883.

Arthur Winslow.—Stadia surveying. Van Nostrand's Science Series, no. 77; New York.

N. Kennedy.—Surveying with the tacheometer. VI+104. London, 1900.

[4]E. Hergesheimer.—A treatise on the plane-table and its use in topographic surveying. Appendix XIII, U. S. Coast and Geodetic Survey Report for 1880. Washington, 1882.

[5]J. A. Flemer.—Phototopographic methods and instruments. U. S. Coast and Geodetic Survey Report for 1897, pp. 619-735. Washington, 1898.

Maps made by reconnoissance methods.[6]
Odometers; pacing; pedometers.
Ordnance maps of England.
Maps made by the U. S. Coast and Geodetic Survey; by the U. S. Geological Survey; by the U. S. Land Office.
Use of township sheets; their strong and weak points.
Spanish grants and irregular surveys.

Elevations.

Vertical location upon maps shown by shading, hachures, or contours.
Importance of elevations in obtaining water supplies; artesian waters; mine draining; prospecting for bedded deposits.
Value of a common datum for elevations; advantages of mean tide level as a datum.
Methods of determining elevations.
Precise levels;[7] ordinary spirit levels; hand levels.
Vertical arc; use of slide-rule in connection with arc observations.
Mercurial barometer; aneroid barometer.[8]
Limitations of each method.
The accuracy should depend upon the demands placed or likely to be placed upon the work.

How to mount and fold maps for use in the field.

Dissect to convenient size, and back with cloth.

Relief maps.[9]

Especially advantageous for showing structural features.

[6]Arthur Winslow.—The construction of topographic maps by reconnoissance methods. Transactions Arkansas Society of Engineers, Architects, and Surveyors; Vol. II, 75-83. 1888.

Bailey Willis.—Graphic field notes for areal geology. Bul. Geol. Soc. Amer. II, 177-188. Rochester, 1891.

H. M. Wilson.—Topographic surveying, including geographic exploratory and military mapping. 884 pp. New York, 1900.

E. C. Eckel.—The preparation of a geologic map. Journal of Geology X, 59-66. Chicago, 1902.

[7]O. H. Tittmann.—Precise levels. Report U. S. Coast and Geodetic Survey for 1879, Appendix XV. Washington, 1881.

Chas. B. Schott.—Results of the transcontinental line of geodetic spirit-leveling near the parallel of 39°. Report U. S. Coast and Geodetic Survey for 1882, Appendix XI. Washington, 1883.

[8]G. K. Gilbert.—A new method of measuring heights by means of the barometer. Second annual report U. S. Geological Survey for 405-562. Washington, 1882.

Edward Whymper.—How to use the aneroid barometer. New York, 1891.

Henry Gannett.—The measurement of altitudes. Mazama I, 243-264. Portland, Oregon, 1897.

F. J. B. Cordeiro.—The barometric determination of heights. London, 1898.

[9]J. H. Harden and E. B. Harden.—The construction of maps in relief. Transactions American Institute of Mining Engineers, XVI, 279-301. New York, 1888.

Cosmos Mindeleff.—Topographic models. National Geographic Magazine I, 254-268. Washington, 1889.

Marcus Baker.—Relief maps. Bul. Phil. Soc. of Washington, XII, 349-368. Washington, 1894.

Data required: horizontal, vertical, geological.
Various methods of making relief maps.

Mine models.[10]

Sections.

How geology is put on maps and sections.
Relation of sections to the map.
The importance of the proper location of structural features illustrated by folds in the coal regions.
The cost of errors.
The difference between general geologic maps and those used in connection with mining operations.
The uses and advantages of an engineer's training in geological work. He can make his own maps.

[10]E. D. North.—Glass mine models. Bul. Amer. Inst. Min. Engs. No. 37, 21-26. New York, January, 1910.

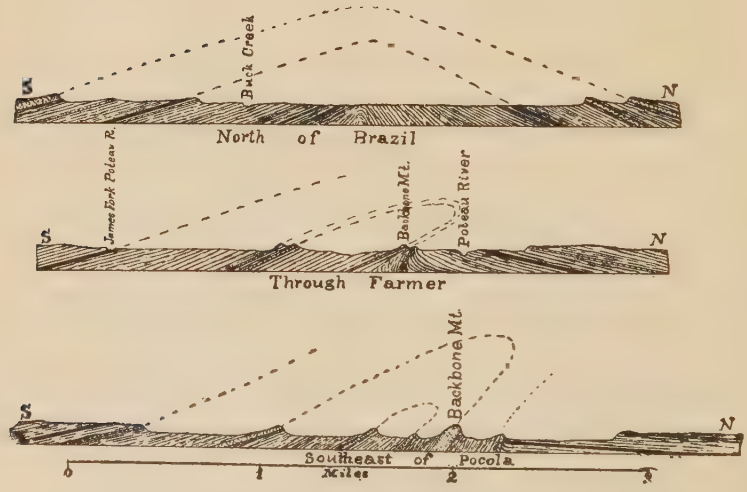

Fig. 1.—North-south sections, ten miles apart, across an anticline in Oklahoma. The heavy black lines represent coal beds; the shaded areas represent shales and the dotted areas sandstones. (Drake.)

GEOLOGICAL SURVEYS.

Immediate objects.

Determining geological formations and structure.
Exhibiting formations and structure on maps and sections.

Ultimate objects.

Turning maps and sections to account.
Knowledge of former physical conditions; the original conditions often determine the contents of the rocks and their present values.

Methods used.

How the rocks are grouped; the use of groups when valuable deposits are confined to certain ones.

How groups or divisions are put on maps.
Method with ordinary maps.
Method with township sheets; inaccuracies of township sheets.
Method with special topographic maps.
Method with maps in construction; the importance of exact locations.

Relations of map scale to the required geologic details.

Field notes should be made on the spot.

Field work is usually best done with reference to the season and the weather.

Office work can be done during inclement weather.

Geologic specimens.

Importance of freshness of the specimens collected: convenient shapes and sizes.

Labeling should be done on the spot; wrapping; boxing.

GEOLOGICAL SURVEYS AND THEIR PUBLICATIONS.

Necessity of knowing what geologic work has been done in a region to be investigated and where the results have been published.

European Surveys.[1]

The geological map of Europe.

[1]Sir A. Geikie.—(Geological survey of Great Britain.) Geological Magazine, V, 306-318, 358-366. London, 1898.

William Topley.—The report upon national geological surveys: Europe. British Association Report for 1884, pp. 221-240. London, 1885.

E. A. Schneider.—Cost of European geological surveys. Engineering and Mining Journal, LXII, 342, 366, 392. New York, 1896.

Geological Surveys by the Federal Government.[2]

Exploring expeditions with geological attachés.
Wheeler survey by U. S. Engineers under the War Department.
Hayden survey, under the Department of the Interior.
Powell survey, under the Department of the Interior.
King survey of the 40th parallel under the War Department.
Present U. S. Geological Survey under the Department of the Interior.
  Its duties as defined are to make a geologic map of the public domain.
  Scope of the work of the federal survey.
    Paleontology, economic geology, topography, mineral statistics, hydrography, irrigation, chemistry, physics, engraving.
Publications.[3]
  Annual reports since 1880 (quartos until 1905-6).
  Monographs (quartos).
  Professional papers (quartos).
  Bulletins (octavos).
  Mineral resources (octavos) from 1882 to date (from 1895 to 1900 they form part of the annual reports).
  Folios of the geologic atlas of the United States show topography and geology, with brief descriptions.
  Topographic sheets.
  How the U. S. Survey reports may be obtained.
  The Bureau of Mines established by Congress in 1910.
  Its functions are the investigations of mine accidents and fuels.

State geological surveys.

State surveys usually established for economic purposes.
  Character of the work and success often depend upon the state geologist.
  Methods of selecting state geologists: appointment, election.
Methods and results of typical state surveys.
  The New York survey.

[2]Surveys of the Territories. House miscellaneous document No 5. 45th Congress, 3rd session.

J. W. Powell.—On the organization of scientific work of the general government. Washington, 1886.

Testimony before the Joint Commission. Senate mis. doc. 82, 49th Congress, 1st session. Washington, 1886.

J. C. Branner.—Relations of state and national geological surveys. Proceedings American Association Advancement of Science, XXXIX, 219-237. Salem, 1891.

S. F. Emmons.—The geology of government explorations. Presidential ad., Geological Society. Washington, 1896.

H. H. Stoek.—Official geology. The Mining Bulletin, II, 38-52. (State College, Pa.) 1896.

[3]In December, 1910, the U. S. Geological Survey had published: 30 annual reports (73 volumes), 50 monographs, 68 professional papers, 432 bulletins, 170 folios, and 19 volumes of mineral resources, besides a large number of topographic sheets.

Pennsylvania survey.
Arkansas survey.

Board of commissioners or control.
Relations and co-operation of national and state surveys.
Aid of state surveys by the U. S. Coast and Geodetic Survey and by the U. S. Geological Survey.

Cost of state surveys.
Appropriations by legislatures.
Special provisions for surveys.

Private geological surveys.

By scientific societies and exploring parties.

By private corporations.
Northern Pacific Railway, coal companies, and other mining companies, for business purposes.

By individuals.

NATURE, ORIGIN AND CLASSIFICATION OF ECONOMIC GEOLOGIC DEPOSITS.

The nature of geologic products.

Great variation in characters in single classes.
Structural materials: stone, glass-sand, slates, asphaltum.
Fuels: coal, lignite, peat, oil, gas.
Ores of base metals: iron, zinc, lead, tin, copper.
Earthy minerals: clays, kaolins, bauxites, fertilizers, chalks.

The origin of geologic deposits.

Geological deposits of economic value originate in ways as widely different as the deposits themselves.

They may be classified according to the processes of their formation as (1) mechanical; (2) chemical; (3) igneous; (4) organic.

The following are illustrations:

I. Mechanical deposits: some building stones, grindstones, marls, clays, sands, some limestones, and marbles.
Mechanical concentrations: placer deposits of gold, diamonds, and tin.

II. Examples of chemical deposits from concentration are salt gypsum.
Deposits from solution on exposure are stalactites, "onyx" marble, and travertine.
Deposits from solution on relief of pressure or lowering of temperature, or both, are many important ore deposits.

III. Poured out as igneous rocks.
Crystallized out in rock masses are feldspar, rutile, diamonds, emery, and certain precious stones.

IV. Examples of organic deposits from plants are peat and coal; from animals: some limestones.
Distillations from organic deposits: petroleum, gas, asphaltum, ozokerite.

Any of these deposits are liable to be changed by metamorphism, and many deposits owe their value to their having passed through such changes.

Following are examples of deposits that owe their value to these changes.

Some marbles are metamorphosed limestones.
Slates are metamorphosed clay shales.
Anthracite is changed coal.
Coal is changed peat.
Kaolin is decayed feldspar.

Relation of the method of its formation to the form and distribution of a deposit of economic value.

The classification of economic geologic deposits.

The classification of geologic deposits is a matter of convenience, and the basis of the classification must be determined by the purposes for which it is intended. Classification may be based upon:

I. Geographic distribution.
   National, state, and local reports.

II. The minerals contained.
   This would group together all similar minerals, regardless of their origin, geographic, or geologic position. Example: hydrocarbons of different origins, various compositions and occurrences.

III. Geologic distribution, or that of the rocks containing the minerals.
   Relations of such grouping to historical geology.

IV. Shape of the deposits.
   Classification of ore deposits by different writers.
   Von Cotta's classification.[1]
   1. Regular deposits.
   2. Irregular deposits.
   Whitney's classification.[2]
   1. Superficial.
   2. Stratified.
      - Constituting the mass of a bed.
      - Disseminated through sedimentary beds.
      - Deposited from solution, metamorphosed.
   3. Unstratified.
      - Irregular
        - Eruptive masses.
        - Disseminated in eruptive rocks.
        - Stockwork deposits.
        - Contact deposits.
        - Fahlbands.
      - Regular
        - Segregated veins.
        - Gash veins.
        - Fissure veins.

   Penrose follows Whitney's classification, with the following modifications:

   Superficial deposits.
   - Stream and littoral.
     - Placers.
     - Stream tin.
     - Magnetic iron sands
   - Bog and lake deposits.
   - Residuary deposits.

   Irregular unstratified deposits.
   - Eruptive and disseminated in eruptives.
   - Impregnations.
   - Reticulated veins.
   - Contact deposits.
   - Chamber deposits.

[1] B. Von Cotta.—A treatise on ore deposits. New York, 1870.
[2] J. D. Whitney.—The metallic wealth of the United States, p. 34. Philadelphia, 1854.

V. Origin and method of formation: genetic.

Kemp's classification of ore deposits.

1. Igneous origin.[3]
2. From solution.
3. From suspension.

Posepny's two classes of ore deposits.[4]

1. Idiogenous (contemporaneous with the rock).
2. Xenogenous (of later origin than the rock).

Crosby's classification of economic deposits.[5]

1. Igneous origin.
2. Aqueo-igneous origin.
3. Aqueous origin.

These and others may be useful each in its place, and according to the purposes for which it is made.[6]

In the present lectures the minerals are taken up separately and no particular classification is followed.

[3]F. D. Adams.—On the igneous origin of certain ore deposits. Montreal, 1894.

J. E. Spurr.—Igneous rocks . . . as related to the occurrence of ores. Transactions American Institute of Mining Engineers, XXXIII, 288-340. New York, 1903.

[4]F. Posepny.—The genesis of ore-deposits. Transactions American Institute of Mining Engineers, XXIII, 197-369. New York, 1894. Also separate publication by the American Institute of Mining Engineers, New York, 1895.

[5]W. O. Crosby.—A classification of economic geological deposits. American Geologist XIII, 249-268. Minneapolis, 1894. Further discussed in Engineering and Mining Journal, LIX, 28. New York, 1895.

R. W. Raymond.—A new classification of economic geological deposits. Engineering and Mining Journal, LVIII, 412-413. New York, 1894.

[6]For other classifications, see Kemp's Ore Deposits, pp. 44-45, and Phillips' Ore Deposits, p. 3.

M. E. Wadsworth.—Report of the state geologist of Michigan for 1891-92, p. 144.

ROCK CAVITIES.

The forms of ore-bodies lead to the belief that some of them are deposited in cavities and many of them in fissures in the rocks. To understand such deposits it is therefore necessary to understand the origins, forms, and relations of rock cavities and fissures.

Two ways of making cavities.

In studying rock cavities it must not be forgotten that the depth at which cavities can remain open is limited, and that they are therefore near-surface phenomena.[1]

Cavities in the crust of the earth may be formed:

I. By solution and removal of portions of the rocks.
II. By fractures caused by shrinkage.
III. By fractures caused by expansion.
IV. By fractures caused by folding.
V. By fractures caused by faulting.

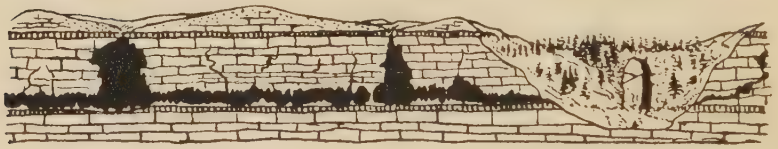

Fig. 2.—Ideal section through a limestone region showing cavities left by solution and removal of portions of the rock. (Shaler.)

I. Cavities formed by solution.[2]

Solvent power of acidulated waters.

Dissolved matter in spring and stream waters.

All the matter in solution has been removed from the rocks through which the water has passed.

Cavities both small and large are produced at comparatively shallow depths by constant action of percolating waters.

[1]F. L. Nason.—The origin of vein cavities. Engineering and Mining Journal, LXXI, 177-179; 209-210. New York, 1901.

William Glenn.—The form of fissure-walls as affected by sub-fissuring and by the flow of rocks. Trans. Amer. Inst. Min. Eng., XXV, 499-513. New York, 1896.

L. M. Hoskins.—Flow and fracture of rocks as related to structure. Sixteenth ann. rep. U. S. Geological Survey, pt. I, 845-874. Washington, 1896.

C. R. Van Hise.—Deformation of rocks. Journal of Geology, IV, 195-213. Chicago, 1896.

[2]E. A. Martel.—Applications géologiques de la spéléologie. Ann. des Mines, 9me sér. X, 5-100. Paris, 1896.

Cave-making by solution is also hastened by mechanical action.

Mammoth Cave of Kentucky has thirty-five to forty miles of tunnels along which one can walk; cavern 70 feet to 200 feet high in places; 12 million cubic yards of rock have been removed.

Caves are common in limestone regions.

More than 100,000 miles of caves in Kentucky.[3] They occur also in Tennessee, Virginia, Indiana, Ohio, Illinois, Iowa, Missouri, and Arkansas.

Caverns are supposed to be formed above drainage, but in some cases they are formed below drainage, and even below sea level.

Mineral bearing breccia sometimes formed in caves.[4]

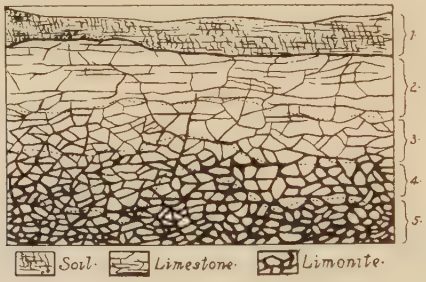

Fig. 3.—Limonite filling cavities in fractured limestone, Wythe county, Virginia. (Benton.)

II. Cavities formed by shrinkage and fracture.

Some rock cavities in which ore deposits have been formed have the appearance of having originated as fractures.

Fractures produced by shrinkage may be due to

a. Contraction produced by cooling.

Deep-seated rocks are highly heated; if by erosion, faulting, or other means, they are brought near the surface, they must cool and shrink.

Expansion for increase of one degree Fahrenheit:
granite, one inch in about 15,000 feet;
slate, one inch in about 14,400 feet;
marble, one inch in about 10,000 feet;
sandstone, one inch in about 8,000 feet.

[3]H. C. Hovey and R. E. Call.—The Mammoth Cave of Kentucky.

[4]J. C. Branner.—The zinc and lead regions of North Arkansas. Ark. Geological Survey, V., Little Rock, 1900.

b. Contraction produced by dolomitization.[5]
Common in some limestone regions.
Shrinkage from dolomitization is twelve per cent.
Breccia.[6]

III. Cavities formed by expansion.

Expansion of rocks, however produced, is liable to open cavities wherever the thrust of the expanded rocks is uneven, or is unevenly resisted.
Expansion may be caused by
a. Hydration, as in the case of anhydrite converted into gypsum by hydration.
b. Elevation of temperature.
c. Growth of crystals as pointed out under "accretion."

IV. Cavities produced by folding of the strata.[7]

Strain caused by lateral pressure.
Relief by fractures along anticlines[8] and synclines.
Ores in anticlines of the saddle reefs in New South Wales.

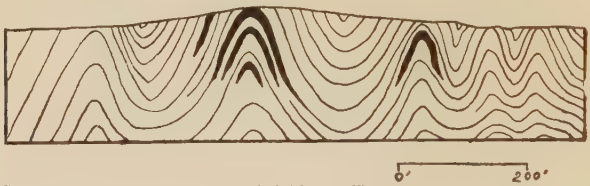

Fig. 4.—Section across the saddle-reef folds at Hargreaves, N. S. Wales. The black areas represent ores deposited in openings at the crests of anticlines.

Manganese in anticlines in Cuba.
Widespread folding of rocks.

V. Fractures and cavities produced by faulting.

Faults are displacements of strata, either vertical or horizontal.
Normal and reversed faults.

[5]E. de Beaumont.—(On dolomitization). Bul de la Soc. Géol. de France, VIII, 174-177. Paris, 1836.
Robert Bell.—Honeycombed limestones in Lake Huron. Bul. Geol. Soc. Amer., VI, 295-304. Rochester, 1895.

[6]A. Winslow.—Lead and zinc deposits of Missouri. Trans. Amer. Inst. Min. Eng., XXIV, 673-674. New York, 1895.
C. H. Gordon.—Origin of the brecciated character of the St. Louis limestone. Journal of Geology, III, 307-311. Chicago, 1895.

[7]A. Daubrée.—Etudes synthétiques de géologie expérimentale, pp. 300-374. Paris, 1879.
Bailey Willis.—The mechanics of Appalachian structure. Thirteenth ann. rep. U. S. Geological Survey, pt. II, 211-281. Washington, 1893.

[8]J. A. Watt.—Saddle reefs at Hargraves. Records of the Geological Survey of N. S. Wales, V, pt. IV, 153-160. Sidney, 1898; VI, pt. II, 83, 1899.
A. C. Spencer.—The manganese deposits of Santiago, Cuba. Engineering and Mining Journal, LXXIV, 247-248. New York, 1902.

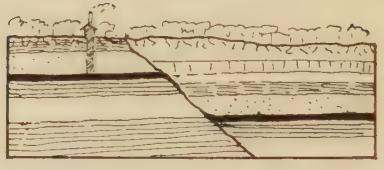

Fig. 5.—Type of a normal fault.

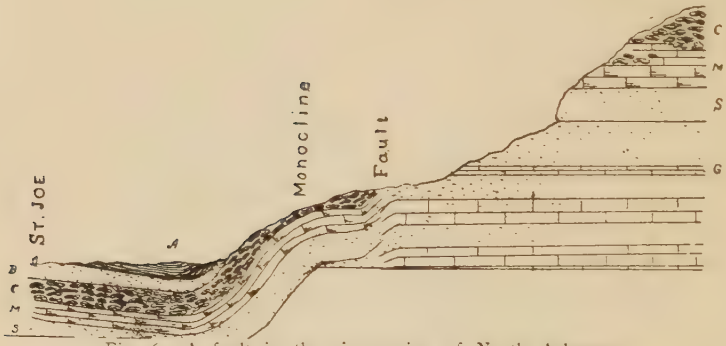

Fig. 6.—A fault in the zinc region of North Arkansas.

Fig. 7.—A fracture and small fault formed during an earthquake in Arizona.

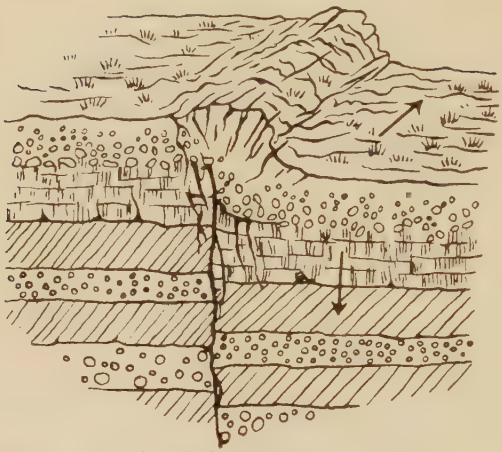

Fig. 8.—Section across a small fault formed during an earthquake in Japan. (Kotô.)

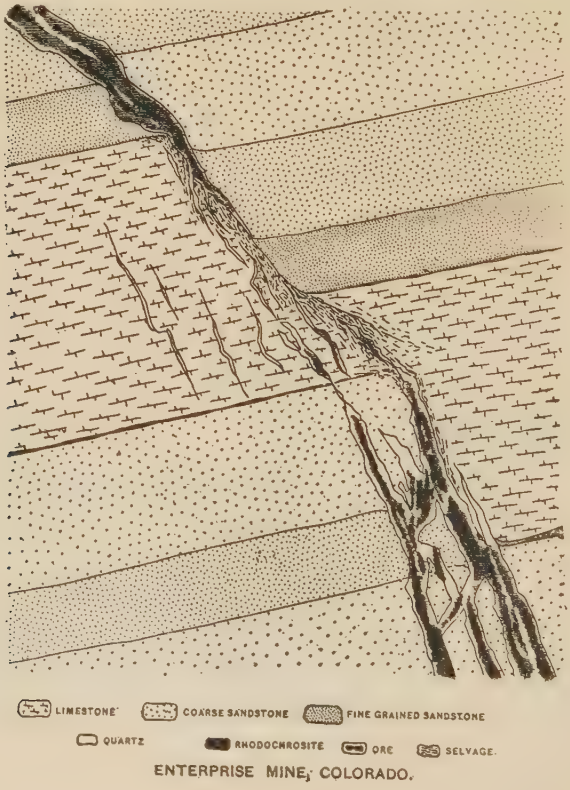

Fig. 9.—A fault containing ore; Enterprise mine, Rico, Colorado. (Rickard.)

Character of fracture depends partly on the character of the rock.

Fault fractures are sometimes filled with debris, or are open enough to permit the percolation of water.

Fractures are sometimes produced by, or at the time of, earthquakes.[9]

Such fractures are commonly accompanied by some, though not necessarily great, faulting.

Examples of Japanese earthquake faults.[10]

Examples of Charleston earthquake.[11]

Debris filling such cavities.

Small fractures may be opened without faults being produced.

Other fractures not included under either of these heads may be produced by any shifting of the strains in the earth's crust, however produced, or by the elevations and depressions of large areas.

DISTRIBUTION OR ARRANGEMENT OF FRACTURES.

The arrangement of fractures is usually irregular.

In a given region, however, there is sometimes a marked regularity in the spacing, direction, and arrangement of fractures.

Notable examples in the zinc regions of Wisconsin.

Rules regarding arrangement and direction that hold in one region, however, are not generally applicable to another.

NOTICE.—It should be kept in mind that the spaces occupied by veins and ore bodies have not necessarily been filled as open cavities. In many instances the veins have been enlarged by accretion; in others they have been made by one mineral replacing another.

[9]W. L. Watts.—Across the Vatna Jökull, or scenes in Iceland, 101, 109, 119, 153-157. London, 1876.

[10]B. Kotô.—On the cause of the great earthquake in central Japan, 1891. Journal of the College of Science, Imperial University of Japan, V, pt. IV. Tokyo, 1893.

[11]C. E. Dutton.—The Charleston earthquake. Ninth ann. rep. U. S. Geological Survey, 203-528. Washington, 1889.

THE FORMATION OF ORE BODIES.[1]

Ore is a metalliferous mineral or rock, especially one of sufficient value to be mined. (Cent. Dict.)[2]

Ore as distinguished from earthy mineral.

Ore deposits as distinguished from other geologic deposits of economic importance.

Following a general genetic classification, ore-bodies occur as:

I. Bedded deposits; II. vein deposits; III. surface deposits of recent date.

I. Bedded deposits contemporaneous with the rocks in which they occur.

The origin of bog iron ores.

Originally surface deposits.

Why they are sometimes interbedded with other rocks.

Fig. 10.—Section in the manganese region of north Arkansas. The black bands represent ores interbedded with the accompanying horizontal rocks.

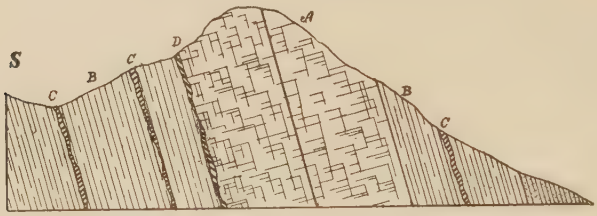

Fig. 11.—Iron ores (C, D) interbedded with folded shales (B) and novaculites (A). (Penrose.)

[1]J. D. Whitney.—The metallic wealth of the United States, 33-68. Philadelphia, 1854.

F. Posepny.—The genesis of ore deposits. New York, 1895.

J. F. Kemp.—The ore deposits of the United States, 28-65. New York, 1893.

L. de Launay.—Formation des gites métallifères. Paris, n. d.

S. F. Emmons.—Theories of ore deposition historically considered. Bul. Geol. Soc. Amer., XV, 1-28. Manchester, 1904.

C. R. Van Hise.—Some principles controlling the deposition of ores. Trans. Amer. Inst. Min. Eng., XXX, 27-177. New York, 1901.

J. H. L. Vogt.—Problems in the geology of ore deposits. Trans. Amer. Inst. Min. Eng., XXXI, 125-169. New York, 1902.

H. V. Winchell.—The genesis of ores in the light of modern theory. Popular Science Monthly, LXXII, 534-542. New York, 1908.

[2]J. F. Kemp.—What is an ore? Jour. Canadian Mining Institute, XII, 356-370. Montreal, 1910.

Changes through which the ore and its accompanying rocks may have passed; folds, faults, erosion, metamorphism, replacement.

The structural features of such ore-bodies are involved in the general structure of the region.

Conglomerate beds subsequently filled; lead mines in bedded deposits at Doe Run, Missouri, and at other places.

Auriferous conglomerates of South Africa.[3]

II. Vein deposits.[4]

"*Veins* are aggregations of mineral matter in fissures in rocks. *Lodes* are therefore aggregations of mineral matter containing ore, in fissures." Von Cotta.[5] In other words *veins* may not contain ore; but *lodes* are veins that do contain ore.

Importance of definitions in law.

The formation of ore-bodies (except surface and bedded deposits) takes place:

a. By the filling of open or brecciated cavities.
b. By the replacement of one mineral by another.
c. By accretion.
d. By the formation of contact deposits.

A. Veins formed by the filling of cavities.

The cavities here meant are not necessarily large open gashes, but they may be waterways through breccia formed in any way.

Examples: the lead and zinc deposits of Wisconsin, Missouri and Arkansas.

The general size and shape of an ore-body formed by the filling of a cavity is necessarily determined by the size and shape of the cavity itself, except in cases of enlargement and replacement as explained below.

[3]Hatch and Chalmers.—The gold mines of the Rand. London, 1895.
T. Reunert.—Diamonds and gold in South Africa. Capetown, 1893.
L. de Launay.—Les mines d'or du Transvaal, 143-158; 177-311. Paris, 1896.

[4]J. A. Phillips.—A treatise on ore deposits, 119-141. 2d ed by Henry Louis, London, 1896.
J. F. Kemp.—The problem of the metalliferous veins. Economic Geology, I, 207-232. 1906.

[5]B. Von Cotta.—A treatise on ore deposits, 26. Translated by F. Prime. New York, 1870.

[6]E. Rahir et J. Du Fief.—De l'action chimique des eaux courantes dans les cavernes ou dans les grands canaux souterrains. Bul. Soc. Belge de Géol., XV, 11-29. Bruxelles, 1901.

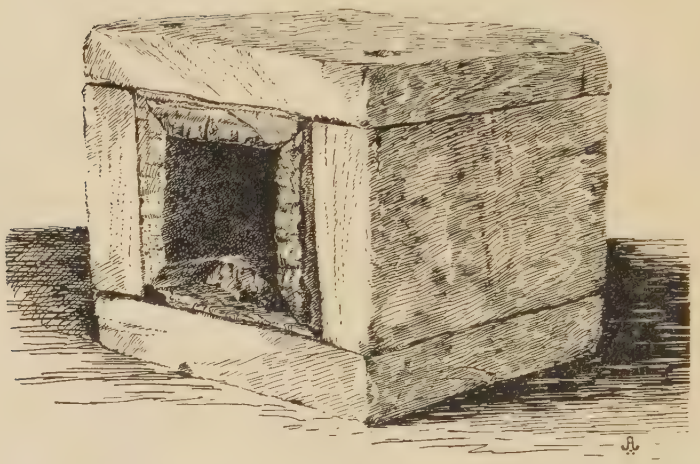

Fig. 12.—Section of a box pipe used for ten years to carry mine water from the 600 to the 1,000 foot level. The water passing through the box lined it with aragonite more than half an inch thick.

Crustification as distinguished from stratification.

Vein matter precipitated from solution on the walls of cavities.

Methods of filling cavities.

Deposition from solutions upon cooling and relief of pressure.[7]

Sublimates deposited by solfataric action.

Origin of the mineral-bearing solutions.

Theory of ascending solutions.[8]

Solubility of gold.[9]

Sandberger's theory of lateral infiltrations.[10]

Relations of the structural features of a region to the origin of different deposits, on account of their influence on the movement of solutions.

Influence of clay beds.

Influence of wall-rock.[11]

[7]H. N. Stokes.—Experiments on the solution, transportation, and deposition of copper, silver, and gold. Economic Geology, I, 644-650. August, 1906.

[8]W. H. Weed.—Ore deposition and vein-enrichment by ascending hot waters. Trans. Amer. Inst. Min. Eng., XXXIII, 747-754. New York, 1903.

[9]A. D. Brokaw.—The solution of gold in the surface alterations of ore bodies. Journal of Geology, XVIII, 321-326. Chicago, 1910.

[10]F. Sandberger.—On the formation of metallic veins. Canadian Naturalist, new ser., VIII, 345-362. Montreal, 1878. American Geologist, XVIII, 393. December, 1896.

C. Klement.—La théorie de la sécrétion laterale. Bul. Soc. Belge de Géol., XII, 121-125. Bruxelles, 1899-1902.

[11]R. A. F. Penrose, Jr.—Some causes of ore shoots. Economic Geology, V, 97-133. March, 1910.

Influence of intersecting fissures.

Influence of local solutions.

Relations of eruptives and of high temperatures generally to the formation of mineral veins.[12]

B. Veins formed by replacement of one mineral by another (metasomatism).

Examples of replacement in the silicification of corals,[13] wood, and shells, and the replacement of organic matter by iron pyrites.

This process is called metasomatic replacement, or metasomatosis.[14]

Replacement in dolomitization.

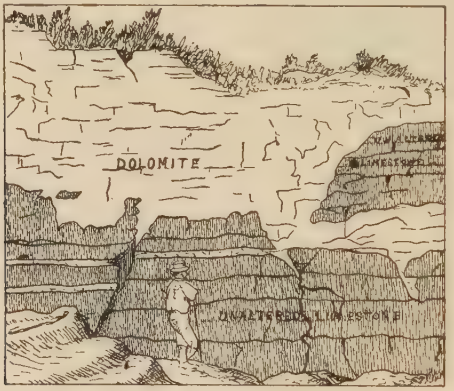

Fig. 13.—Section in a quarry at Kilkenny, Ireland, showing the unaltered limestone and the dolomite. (Prestwich.)

[12]J. F. Kemp.—The rôle of the igneous rocks in the formation of veins. Trans. Amer. Inst. Min. Eng., XXXI, 169-198. New York, 1902; XXXIII, 699-714. New York, 1903.

W. H. Weed.—Ore deposits near igneous contacts. Trans. Amer. Inst. Min. Eng., XXXIII, 715-746. New York, 1903.

[13]Chemical News, V, 95; Jour. Chem. Soc., XV, 107.

[14]C. R. Van Hise.—Metasomatism. Sixteenth ann. rep. U. S. Geological Survey, pt. 1, 689-694. Washington, 1896.

W. Lindgren.—Metasomatic processes in fissure-veins. Trans. Amer. Inst. Min. Eng., XXX, 578-692. New York, 1901.

James Park.—Metasomatic replacement. Engineering and Mining Journal, LXXIX, 799. New York, 1905.

C. H. Smyth, Jr.—Replacement of quartz by pyrite and corrosion of quartz pebbles. Amer. Jour. Sci., CLXIX, 277-285. New Haven, 1905.

W. Lindgren.—Metasomatic processes in the gold deposits of western Australia. Economic Geology, I, 530-544. June, 1906.

J. M. Boutwell.—Genesis of the ore-deposits of Bingham, Utah. Trans. Amer. Inst. Min. Eng., XXXVI, 541-580. New York, 1906.

C. Veins formed by enlargement or accretion.

Enlargement of quartz grains.

Illustration of needle ice and crystallization in the soil.

"I venture the suggestion that these minerals (quartz and calcite) in crystallizing, have exerted a force analagous to the expansion of water on freezing, which has crowded the rock fragments asunder." I. C. Russell.[15]

The size, form, and structural relations of certain geodes due to enlargement.[16]

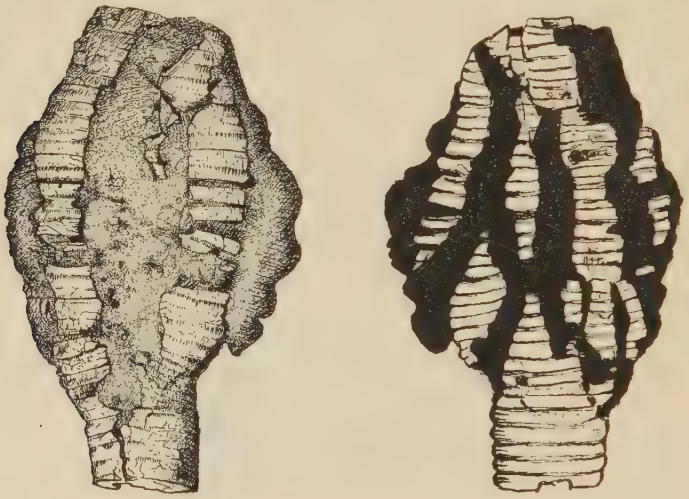

Fig. 14.—A geode formed in the stem of a crinoid. An illustration of the mechanical force of the crystallization of quartz.

Evidences of the mechanical force of the process.[17]

Possible relations to vein enlargement and to brecciation.

D. Contact deposits.

The formation of contact deposits is a phase of contact metamorphism due to the combined action of heat, water, and gases.[18]

[15]I. C. Russell.—Twentieth ann. rep. U. S. Geological Survey, pt. II, 207. Washington, 1900.

[16]N. S. Shaler.—Formation of dikes and veins. Bul. Geol. Soc. America, X, 253-262. Rochester, 1899.

[17]Becker and Day.—The linear force of growing crystals. Proc. Washington Acad. Sci., VII, 283-288. Washington, 1906.

R. A. Daly.—The calcareous concretions of Kettle Point, Lambton county, Ontario. Journal of Geology, VIII, 135-150. Chicago, 1900.

[18]W. Lindgren.—The character and genesis of certain contact-deposits. Trans. Amer. Inst. Min. Eng., XXXI, 226-244. New York, 1902.

J. F. Kemp.—The rôle of the igneous rocks in the formation of veins. Trans. Amer. Inst. Min. Eng., XXXI, 169-198. New York, 1902.

W. H. Weed.—Contact metamorphic and other ore deposits near igneous contacts. Engineering and Mining Journal, LXXIV, 513. New York, 1902.

The enrichment of veins.[19]

Enrichment affected by climatic conditions, topography, nature of the ores and of the wall-rocks.[20]

III. Deposits of recent date, at or near the surface.[21]

The usual classification of mineral deposits as "surface deposits" is open to the objection that many of these are no longer either at or near the surface. Examples: iron ores of carboniferous age; placer gold of Cretaceous age.[22]

Surface deposits are local, and are forming at present; they are formed (1) by mechanical concentration; (2) by chemical action.

A. Deposits formed by mechanical concentration.

Mechanical concentrations commonly result from the decay of rocks and the mechanical concentration of certain of the minerals contained in the original rocks.

Such concentration may be due to differences in specific gravities of the minerals, or to differences in hardness.

Stream and litoral deposits.

Placer gold.
Stream tin.
Magnetic iron sands.
Monazite and zircon sands.
Brazilian diamonds.

B. Deposits formed by chemical action.[23]

Surface deposits from chemical action or from chemical alterations at the surface may result in the modification of original deposits or in the production of new ones.

Examples of new surface deposits are bog iron ores, salt gypsum, nitre, soda.

Incrustations of smithsonite and "Mexican onyx."

[19]W. H. Weed.—Enrichment of mineral veins by later metallic sulphides. Bul. Geol. Soc. Amer., XI, 179-206. Rochester, 1900.

W. H. Weed.—The enrichment of gold and silver veins. Trans. Amer. Inst. Min. Eng., XXX, 424-448. New York, 1901.

A. L. Collins.—Trans. Amer. Inst. Min. Eng., XXXI, 951-953. New York, 1902.

[20]J. E. Spurr.—Enrichment in fissure veins Engineering and Mining Journal, LXXX, 597-598. New York, 1905.

[21]For references see titles given under the heads of the minerals mentioned as examples.

[22]R. L. Dunn.—Auriferous conglomerate in California. Twelfth rep. State Mineralogist, 459-471. Sacramento, 1894.

[23]Edward Steidtmann.—A graphic comparison of the alteration of rocks by weathering with their alteration by hot solutions. Economic Geology, III, 381-409. July-Aug., 1908.

Some ore-bodies and deposits, though not necessarily deposited by chemical action, owe their value to chemical alterations at or near the surface.

Certain residuary deposits are produced by chemical action and mechanical concentration.

Manganese ores of Arkansas, Georgia, Virginia, and Brazil.

Gossan, the altered part of a lode.

Kaolins and clays formed by the decomposition of feldspars.

Fullers' earth in Arkansas made by the weathering of a clay.

THE FEATURES OF ORE DEPOSITS.

The features of ore deposits, their shape, structure, and general relations, depend partly upon the methods of their formation, that is, whether they were laid down as bedded deposits contemporaneous with their accompanying rock beds, or were deposited later in cavities, or occur as replacements, alterations, or contact deposits.

General forms.

Shapes of cave deposits.

The shapes of bedded deposits are determined by the conditions of deposition. Examples: the iron ores of Pennsylvania; the phosphate deposits of Arkansas and Tennessee.

Shapes of fissure deposits.

Fissure veins.[1]

"A fissure vein is a mineral mass occupying a fissure in the earth's crust."—R. W. Raymond.

Gash,[2] lenticular, bedded, and contact veins.

Fig. 15.—A gash vein in the magnesian limestone of Wisconsin. (Chamberlin.)

Irregularities of thickness.

Irregularities of direction, outcrop, dip, and strike.

Groups of veins; feeders, ore-shoots, or chimneys.

[1]What is a fissure vein? Economic Geology, I, 38; 167-172; 282-286; 385-387; 481-484; 700-702. 1906.

[2]For illustrations of gash veins, see Twentieth ann. rep. U. S. Geological Survey, pt. VII, 420. Washington, 1900.

Parallelism of veins.

Produced by torsion or other fractures, or by bedding.

Complications produced by faulting.[3]

Fig. 16.—Illustration of reversed faults that have displaced the beds but have left them parallel.

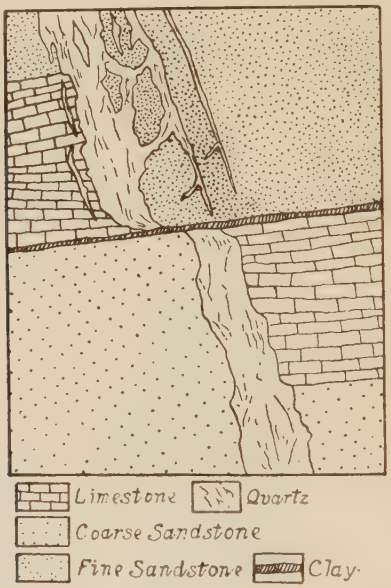

Fig. 17.—Section in the Enterprise mine, Rico, Colorado, showing both vertical and horizontal faulting. (Rickard.)

Effect of vertical displacements; of lateral displacements.

Complications by intersection of several ore deposits.

Mother lode of California 112 miles long.[4]

Size and extent of ore deposits.

Uncertainties regarding the size and form of ore-bodies.

[3]See illustrations by Philip Argall, Engineering and Mining Journal, LXXXVI, 366-7. New, York, 1908.

[4]H. W. Fairbanks.—Geology of the mother lode region. Tenth ann. rep. State Mining Bureau of California, 23-90.

Internal and structural features.

Banded structures produced by crustification.

Brecciated structure produced by cementing of fractured materials.

Definition of terms.

Hanging-wall; foot-wall; country rock.

Selvage, gouge, or flucan is the clay seam between a vein and the wall-rock.

Possible relation of clay to the vein matter.

Ore.

Gangue.

Association of ores and gangues.

Some veins are sharply defined; others merge into their walls.

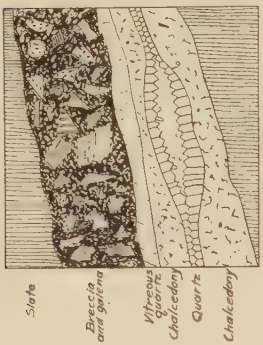

Fig. 18.—A vein brecciated on one side and banded on the other. (Foster.)

Fig. 19.—Ore-bearing quartz. The country rock is altered but contains no ore. (Lindgren.)

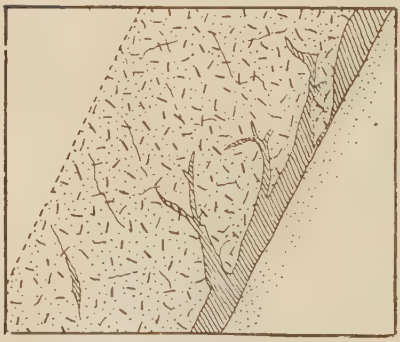

Fig. 20.—Quartz vein along the foot-wall of a porphyry dike with stringers running into the porphyry. (Lindgren.)

Fig. 21.—Vein with its ores extending into the altered country rock. (Lindgren.)

Distribution of ores in veins.

Distribution due to variation in the size of the vein.

Distribution due to other causes.

Vugs; lenses.

Bonanzas are ore pockets or local enlargements of veins.[5]

Horses; stringers; shoots;[6] chimneys.

Effect of change of dip on the character of the lode.

Effect of country rock on the lode.[7]

In Swaledale, Yorkshire, the lead ores are richest in the limestones and poorest in the grits and shales.

Ore-bodies are often found at the contact between two formations.

Fig. 22.—A horse with the vein passing around it on both sides. (Foster.)

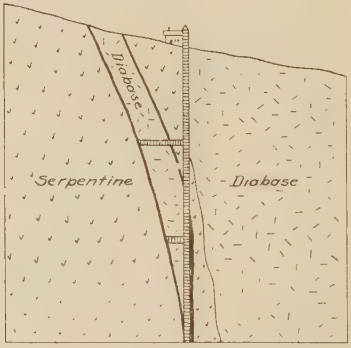

Fig. 23.—Contact vein, Grass Valley, Cal. (Lindgren.)

Fig. 24.—Sheeted vein structure and minor fissures, Ajax mine, Cripple Creek, Colo. (Lindgren and Ransome.)

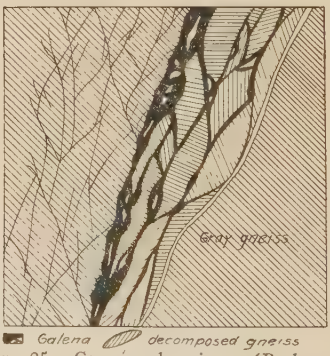

Fig. 25.—Compound vein. (Beck and Weed.)

Ores affected by superficial alteration.[5]

Oxidation at the immediate surface.

Gossan, *colorado, chapeau de fer, eisener hut.*

Origin of these names from the rusty brown color of the oxidized ores.

In arid regions the surface is not always deeply oxidized or colored.

Why free gold near the surface is replaced by sulphides in depths.

Depths to which alterations extend and the nature of the changes with various ores. From 15 to 1,500 feet.

Copper ores in Chile are affected to a depth of 1,500 feet.

Case of the Ducktown copper mines in East Tennessee.

Silver in Granite Mountain, Montana, affected to a depth of 900 feet.

Gold in soft schists in the Gongo Soco mines in Brazil at 378 feet.

Zinc changed to carbonate to the depth of weathering.

Effect of these changes upon the value of the ores.

Different treatment required for the different kinds of ores.

[5]T. A. Rickard.—The formation of bonanzas in the upper portions of gold-veins. Trans. Amer. Inst. Min. Eng., XXXI, 198-220. New York, 1902.

[6]W. H. Weed.—Ore shoots. Engineering and Mining Journal, LXXXII, 196. New York, 1906.

[7]L. Bradley.—An inquiry into the deposition of lead ore. London, 1862.

[8]R. A. F. Penrose, Jr.—The superficial alteration of ore deposits. Journal of Geology, II, 288-317. Chicago, 1894.

Part II

The Metallic Minerals

IRON.[1]

The prevalence of iron in the rocks.

Uses.

Of all the metals, iron in its various forms is the one in most common use in the manufacture of tools, machinery, and constructions of all kinds.

Ores.

Iron is seldom found in the native state; some meteorites are native iron. The ores of iron are oxides, carbonates, and sulphides.

The oxides are anhydrous and hydrous.

Anhydrous oxides.

Hematite (Fe_2O_3), oxygen 30, iron 70, if chemically pure. This is the most important of the American ores.

Specular iron.

Red hematite, called "kidney" ore when it is reniform.

Fossil ore.

Itabirite, iron schist.

Red ochre.

Magnetite (Fe_3O_4), oxygen 27.6, iron 72.4.

Magnetic ore is often titaniferous.[2]

Franklinite deposits of New Jersey.

Hydrous oxides.

Limonite, or brown hematite ($2Fe_2O_3 . 3H_2O$), oxygen 25.7, water 14.5, iron 59.8.

Bog iron.

Bombshell ore.[3]

Ochres (excepting red ochre).

Other forms of limonite.

Turgite: oxygen 28.5, iron 66.2, water 5.3.

Goethite: oxygen 27, iron 62.9, water 10.1.

[1]James M. Swank.—History of the manufacture of iron in all ages. Philadelphia, 1884.

J. P. Lesley.—The iron manufacturer's guide. New York, 1859.

[2]J. F. Kemp.—A brief review of the titaniferous magnetites. School of Mines Quarterly, XX, 323-356; New York, 1899; XXI, 56-65; New York, 1899.

[3]H. M. Chance.—The origin of bombshell ore. Proc. Am. Phil. Soc., XLVII., 136. Philadelphia, 1908.

Carbonates.

Siderite, or spathic iron ($FeCO_3$), carbon dioxide 37.9, iron protoxide 62.1, equivalent to 48.3 metallic iron.

Clay ironstone.

Blackband.

Brown carbonate.

Sulphides.

Iron pyrites (FeS_2), sulphur 53.4, iron 46.6. Used in the manufacture of sulphur and sulphuric acid. (See under Iron Pyrites.)

Modes of occurrence and association of the ores of iron.

Hematite is commonly a replacement and as contact deposits in rocks of all ages.

Magnetite occurs in metamorphic and igneous rocks, as contact deposits, and as sands on lake, river, or sea shores.

Limonite commonly originates as a bog ore in swamps or ponds, or it may be formed by the weathering of some iron bearing mineral.

Carbonate commonly occur as concretions in shales and clays.

The origin of iron ores.[4]

Black iron sands.[5]

The magnetite of black iron sands forms a source of supply of useful iron ore on the Pacific coast.

Separation of mixed ores by magnetic processes.[6]

Impurities found in the ores of iron.

Phosphorus makes iron brittle or "cold short."

Sulphur makes iron brittle at a red heat, or "hot short," and destroys its welding power.

Silica: over 37% ruins the tenacity of iron, making it "rotten short."

[4]T. S. Hunt.—The genesis of certain iron ores. Canadian Naturalist, new series, IX, 431-433. Montreal, 1881.

Bibliography of the origin of iron ores. Bul. 6, Geological Survey of Minnesota, 258-334. Minneapolis, 1891.

J. S. Newberry.—The genesis of our iron ores. School of Mines Quarterly, II, 1-17. New York, 1880.

H. M. Chance.—The pyritic origin of iron ore deposits. Engineering and Mining Journal, LXXXVI, 408-410. New York, 1908.

H. M. Chance.—A new theory of the genesis of brown hematite ores. Trans. Am. Inst. Min. Eng., XXXIX, 522-539. New York, 1909.

E. J. Moore.—The occurrence and origin of some bog iron deposits in the district of Thunder Bay, Ontario. Economic Geology, V, 528-537. Sept., 1910.

[5]D. T. Day and R. H. Richards.—Useful minerals in the black sands of the Pacific Slope. Mineral resources of the United States for 1905, 1175-1258. Washington, 1906.

R. H. Richards.—Black sand of the Pacific Coast. Technology Quarterly, XIX, 163-166. Boston, 1906.

[6]O. Bilharz.—Industrial importance of the process of magnetic separation of iron ores as invented by J. P. Wetherill. Frankfurt, 1899.

Titanium: over 3% renders iron very difficult to fuse.

Arsenic softens steel, reduces its tenacity, and 1.6% destroys its malleability.

Antimony: .1 to .2% makes it "cold or hot short."

Processes have been devised for using ores containing impurities.

The Thomas-Gilchrist process of steel making uses pig iron high in phosphorus.

The Clapp-Griffiths process permits much phosphorus when silicon is carefully excluded.

The Bessemer process of decarburizing cast iron, by which steel is cheapened.

Bessemer ore should not contain more than .05 per cent phosphorous.

Non-Bessemer iron ore.

In general the impurities that damage ore for one purpose may be beneficial for some other.

The properties that determine the value of iron ores are the high percentage of iron, and the low percentage of impurities.

Distribution of the Ores of Iron.

Geological.

Iron is found in rocks of all ages, but is of more importance in some than in others.

Pre-Cambrian iron of Lake Superior.

Cambro-Silurian iron of Brazil.

Silurian ore of Missouri.

Archean, Cambro-Silurian, Silurian, and Carboniferous iron belts of the Appalachians.

Tertiary iron of Texas and Arkansas.[7]

Iron deposits are forming at the present time.

Geographical.

Foreign iron regions.

United Kingdom,[8] Germany, France, and Russia are the principal foreign producers.

Spain.[9]

[7]R. A. F. Penrose, Jr.—The iron deposits of Arkansas. Geological Survey of Arkansas for 1892, I. Little Rock, 1892.

[8]J. D. Lockwood.—The iron ores of Great Britain and Ireland; their mode of occurrence and origin. London, 1893.

[9]E. Mackay-Heriot.—The Bilbao iron mines. Engineering and Mining Journal, LXXVI, 510-512. New York, 1903.

Scandinavia.[10]

Great variety of ores and wide range of associated rocks.

Bog ores have been worked since very early times.

Siberia.[11]

New South Wales.[12]

The iron ore reserves of the world.[13]

Professor Törnebohn of the Swedish government estimates the total available world's supply at ten billion tons of ore. This, at the present rate of consumption, will last 50 years.

One-fourth of world's original iron resources has been used.

The most conservative estimates show that the iron deposits of the United States can last only about one hundred years. After that low grade ores must be used.

Distribution in America outside of United States.

Brazil contains extensive deposits of good ore, but is now producing very little.[14]

Cuba.[15]

Bessemer magnetite ores of metamorphic origin, being replacements in igneous gabbros.

Canada.[15]a

IRON REGIONS OF THE UNITED STATES.[16]

There are three general regions: Appalachian region; Lake Superior region; western region.

[10]H. Sjögren.—The geological relations of the Scandinavian iron ores. Trans. Amer. Inst. Min. Eng., XXXVIII, 766-835. New York, 1908.

[11]P. Kovalew.—Gisements de fer du Mont Irkouskan. Mémoires du Comité Géologique. Nouv Sér., VI, 121-126. St. Petersburg, 1903.

[12]J. B. Jaquet.—The iron ore deposits of New South Wales. Memoirs of the Geological Survey of N. S. Wales. Sydney, 1901.

[13]C. K. Leith.—Iron ore reserves. Economic Geology, I, 360-368. Feb.-March, 1906.

The iron ore resources of the world. Eleventh International Geological Congress, 2 vols. and atlas. Stockholm, 1910.

[14]H. K. Scott.—The iron ores of Brazil. Journal of Iron and Steel Inst., LXI, 237-254. London, 1902.

O. A. Derby.—The iron ores of Brazil. The iron ore resources of the world, 813-822. Stockholm, 1910.

[15]A. C. Spencer.—The iron ores of Santiago, Cuba. Engineering and Mining Journal, LXXII, 633-634. New York, 1901.

A. C. Spencer.—Three deposits of iron ore in Cuba. Bul. 340, U. S. Geological Survey, 318-329. Washington, 1908.

[15]aEugene Haanel.—The iron ores of Canada. The iron ore resources of the world, 721-743. Stockholm, 1910.

[16]Raphael Pumpelly.—The mining industries of the United States (exclusive of the precious metals). Tenth census, XV. Washington, 1880.

C. W. Hayes.—The iron ore supply of the United States. Bul. 28, Amer. Inst. Min. Eng., 373-379. New York, 1909.

J F. Kemp.—Iron ore reserves in the United States. The iron ore resources of the world, 755-777. Stockholm, 1910.

I. The Appalachian region ores mostly non-Bessemer.

Iron occurs in four general northeast-southwest belts following the geological structure.

Beginning with the easternmost, these are:

Archæan belt: ores chiefly lenticular deposits of magnetite in gneisses and other metamorphic rocks. This belt is most important in the Adirondacks.[17] New York, New Jersey, and Virginia.

Cambro-Silurian belt: ores chiefly non-Bessemer limonites, associated with schists, limestones, and clays. This belt is most important in Virginia, Alabama, Tennessee, and Pennsylvania.

Upper-Silurian belt: ores non-Bessemer red hematites, "fossil ore," limited to the Clinton beds, which contain intercalated beds of iron ore almost everywhere that they occur. They are of the greatest importance in the Birmingham, Ala.,[18] district, where they are the chief source of supply.

Carboniferous belt: carbonate ores which are of little importance at present. Western Pennsylvania, Ohio, and Kentucky ores are of this type.

The most important producing states in the Appalachian region, in the order of their importance in 1897, are:

Alabama.[19]

Production in 1906, 1,397,014 tons.

Ores: Non-Bessemer hematites in the Clinton beds of the Upper Silurian are the most important.[20]

Brown hematites (limonite) belonging to the Cambro-Silurian belt are also important.

Associated rocks.

Birmingham is the chief district.

[17]E. C. Eckel.—Brown hematite deposits of eastern New York and western New England. Engineering and Mining Journal, LXXVIII, 432-434. New York, 1904.

J. F. Kemp.—The titaniferous iron ores of the Adirondacks. Nineteenth ann. rep. U. S. Geological Survey, pt. III, 377-422. Washington, 1899.

W. O. Crosby.—Geological history of the hematite iron ores of the Antwerp and Fowler belt in New York. Technology Quarterly, XIV., 162-170. Boston, 1901.

[18]Burchard, Butts and Eckel.—Iron ores of the Birmingham district, Alabama. Bul. 400, U. S. Geological Survey. Washington, 1910.

[19]W. B. Phillips.—Iron-making in Alabama. Geological Survey of Alabama, 1896. 2d ed. Montgomery, 1898.

[20]E. C. Eckel.—The Clinton hematite. Engineering and Mining Journal, LXXIX, 897-898. New York, 1905.

E. F. Burchard.—The Clinton iron ore deposits in Alabama. Trans. Amer. Inst. Min. Eng., XL, 75-133. New York, 1910.

Pennsylvania.[21]

Product in 1908, 11,348,549 tons.

Ores: The Archæan magnetites and Cambro-Silurian limonites in the eastern part of the state are the most important; hematites and carbonites are of little importance.

Virginia.[22]

Production in 1905, 320,458 tons.

Ore: chiefly limonite.

Geological relations of the ores.

The Rich Patch deposits.[23]

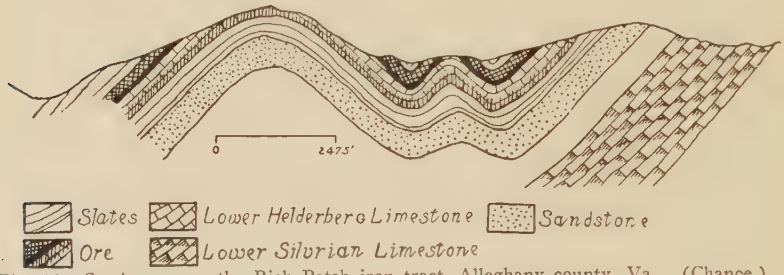

Fig. 26.—Section across the Rich Patch iron tract, Alleghany county, Va. (Chance.) The left end of the section is north.

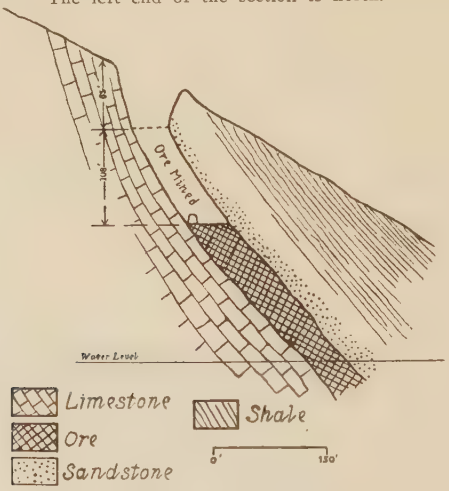

Fig. 27.—Section through an open cut at the Rich Patch mines, Alleghany county, Va. (Chance.)

[21]T. C. Hopkins.—The Cambro-Silurian limonite ores of Pennsylvania. Bul. Geological Society of America, XI, 475-502. Rochester, 1900.

[22]Geological Atlas, U. S. Geological Survey. Staunton folio. 1894.

[23]H. M. Chance.—The Rich Patch iron tract, Virginia. Trans. Amer. Inst. Min. Eng., XXIX, 210-223. New York, 1900.

Tennessee.[24]

Production in 1897, 677,037 tons; value per ton at the mines, $0.71.

Ores: red hematite and limonite of non-Bessemer quality.

Localities and geological relations of the Tennessee ores.

Other producing states in the eastern or Appalachian regions are:

New York: ores chiefly magnetite from Archæn rocks. Also Cambro-Silurian.

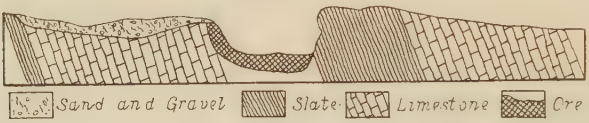

Fig. 28.—Section showing the geology of the Cambro-Silurian iron ores of the Amenia mine, Dutchess county, N. Y. (Putnam.)

New Jersey: magnetites in Archæan rocks.

Georgia.[25]

Maryland.[26]

North Carolina, Ohio, Kentucky.

Relative production and geological relations of the ores.

II. The Lake Superior Region.[27]

Ores: hematites and magnetites, usually of Bessemer quality.

The ores occur in masses associated with greatly disturbed schists, jaspers, cherts, and quartzites, of pre-Cambrian age.

Soapstone is often an important associated rock.

Importance of dikes in the Gogebic range.

Extent of the ore bodies.

Norrie mines; Lake Angeline mine; Biwabik mine.

[24]Geological Atlas of the U. S. Geological Survey. Ringgold, Sewanee, Cleveland, Chattanooga, and Loudon folios.

F. L. Garrison.—The iron ores of Shady Valley, Tennessee. Engineering and Mining Journal, LXXVIII, 590-592. New York, 1904.

[25]T. L. Watson.—The yellow-ocher deposits of the Cartersville district, Bartow County, Ga. Trans. Amer. Inst. Min. Eng., XXXIV, 643-666. New York, 1904.

C. W. Hayes.—Geological relations of the iron-ores in the Cartersville district, Ga. Trans. Amer. Inst. Min. Eng., XXX, 403-419. New York, 1901.

S. Mays Ball.—Review of fossil iron ore deposits of Georgia. Engineering and Mining Journal, LXXXVIII, 200-204. New York, 1909.

S. W. McCallie.—Notes on the fossil iron ores of Georgia. Engineering and Mining Journal, LXX, 757. New York, 1900.

[26]J. T. Singewald, Jr.—The iron ores of Maryland. Economic Geology, IV, 530-543. 1909.

[27]J. Head and A. P. Head.—The Lake Superior iron ore mines. Cassier's Magazine, XVI, 623-646. Oct., 1899.

C. K. Leith.—A summary of Lake Superior geology with special reference to recent studies of the iron-bearing series. Trans. Am. Inst. Min. Eng., XXXVI, 101-153. New York, 1905.

Theories regarding the origin of the ores.[28]

Sedimentary origin; organic origin; igneous origin; replacements.

The principal districts or "ranges" are:

a. The Menominee range[29] is mostly in Michigan, forty miles west of Lake Michigan along the Menominee River, near the boundary between Michigan and Wisconsin.

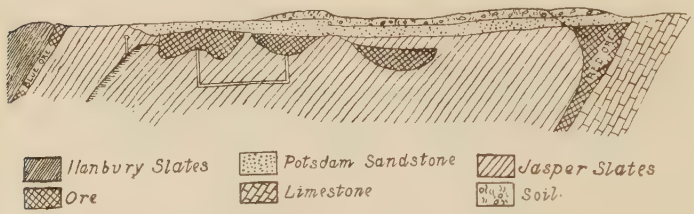

Fig. 29.—Section through the Cyclops an Norway mines in the Menominee iron region, Michigan. North is to the right. (Fulton.)

Ores: soft hematites of Bessemer and non-Bessemer quality, containing 60% to 67% iron.

b. The Marquette range,[30] Michigan, is best developed near the towns of Marquette and Ishpeming.

Ores: magnetites, and hard and soft hematites, mostly of Bessemer quality.

Analysis gives 68.4% metallic iron, .053 phosphorus, 2.07 silica.

Geological relations and occurrence.

Lower Huronian much folded and contains many dikes.

c. The Penokee-Gogebic range,[31] (called the Gogebic range), passes from Wisconsin into Michigan at the town of Ironwood.

Ores: soft hematites of high grade Bessemer quality; 60 to 66 per cent iron.

[28]J. E. Spurr.—The original source of the Lake Superior iron ores. American Geologist, XXIX, 335-349. Minneapolis, 1902.

C. K. Leith.—Genesis of Lake Superior iron ores. Economic Geology, I, 47-66. 1906.

[29]W. S. Bayley.—The Menominee iron-bearing district of Michigan. Monograph XLVI, U. S. Geological Survey. Washington, 1904.

[30]C. R. Van Hise and W. S. Bayley.—Preliminary report on the Marquette iron-bearing district of Michigan. 15th ann. rep. U. S. Geological Survey, 1893-94, 477-650. Washington, 1895.

C. R. Van Hise, W. S. Bayley and H. L. Smyth.—The Marquette iron-bearing district of Michigan. Monograph XXVIII, U. S. Geological Survey. Washington, 1897.

J. M. Clements and H. L. Smyth.—The Crystal Falls iron-bearing district of Michigan. Monograph XXXVI, U. S. Geological Survey. Washington, 1899.

[31]R. D. Irving and C. R. Van Hise.—The Penokee iron-bearing series. Monograph XIX, U. S. Geological Survey. Washington, 1892. (Bibliography.)

C. R. Van Hise.—The iron ores of the Penokee-Gogebic series of Michigan and Wisconsin. American Journal of Science, CXXXVII, 32-48. New Haven, 1889.

The ore bodies are concentrated in the apices of V-shaped troughs formed by southward dipping dikes cutting northward dipping impervious strata. They are intimately associated with cherts, which were originally heavily charged with carbonate ore. These carbonate ores underwent chemical change, and by solution and metasomatic replacement were concentrated in the troughs (Van Hise).

d. The Baraboo range[32] is in Columbia county, in the center of the southern half of Wisconsin.

Ore occurs in synclinal fold of Freedom formation with slates, cherts, and dolomites.

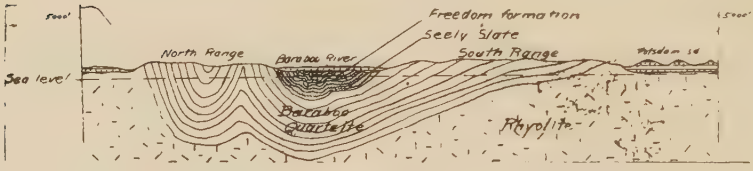

Fig. 30.—A generalized north-south section across the Baraboo iron district. (Wiedman.)

e. The Vermillion range[33] at Vermillion Lake is in northeast Minnesota, near the Canadian border.

Tower and Ely are the principal mining towns.

Ores: mostly hard hematites of Bessemer and non-Bessemer quality, with from 60 to 67 per cent of iron. They are closely associated with schists, "jaspillites," and quartzites. The ore masses are in sedimentary rocks, and were probably concentrated by metasomatic replacement.

f. The Mesabi range[34] is southwest of the Vermillion range in Minnesota. Its first ore shipments of importance were made in 1893.

[32]O. Rohn.—The Baraboo iron range. Engineering and Mining Journal, LXXVI, 615-617. New York, 1903.

N. H. Winchell.—The Baraboo iron ore. American Geologist, XXXIV, 242-253. Minneapolis, 1904.

[33]N. H. Winchell.—The iron range of Vermilion Lake. 15th ann. rep. Geology and Natural History Survey of Minnesota for 1886, 217 et seq. St. Paul, 1887.

N. H. Winchell and H. V. Winchell.—The iron ores of Minnesota. Bul. VI, Minnesota Geological Survey. Minneapolis, 1891.

J. M. Clements.—The Vermilion iron-bearing district of Minnesota. Monograph XLV, U. S. Geological Survey. Washington, 1903.

[34]U. S. Grant.—Sketch of the geology of the eastern end of the Mesabi iron range in Minnesota. Engineer's Year Book, University of Minnesota, 49-62. 1898.

C. K. Leith.—The Mesabi iron-bearing district of Minnesota. Monograph XLIII, U. S. Geological Survey. Washington, 1903.

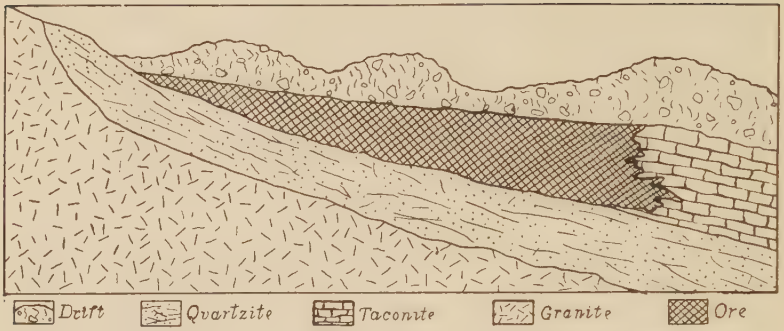

Fig. 31.—Section showing the usual occurrence of iron ores in the Mesabi range. It is below the drift and rests upon quartzite. (Winchell.)

Ores: mostly soft hematites of Bessemer quality. The associated rocks are slates, quartzites, and jasper, all covered by glacial debris. The ore masses are probably the result of metasomatic replacement.

g. The Cayuna range in Minnesota.[35]

Comparative importance of the districts in the Lake Superior region. The influence of transportation facilities.[36]

III. The western region.

This region includes the iron producing states west of the Missouri river.

Missouri:[37] two localities have been of considerable importance.

a. Iron Mountain: hard hematite ores about a porphyry hill.
Iron boulders: residuary deposit, from the weathering of porphyry.

b. Pilot Knob: ore hard specular hematite, in two beds, associated with "slate" and porphyry sheets.

These ores are thought by Nason to be of sedimentary origin.

The Cherry Valley ore bank.

Other western iron regions:
Colorado[38] is the most important producer.

[35]C. K. Leith.—The geology of the Cuyuna iron range, Minn. Economic Geology, II, 145-152. 1907.

[36]W. Fawcett.—The new era in lake shipping. Engineering and Mining Journal, LXIX, 467-468. New York, 1900.

[37]Frank L. Nason.—A report on the iron ores of Missouri. Geological Survey of Missouri, 1892, II. Jefferson City, 1892.
Raphael Pumpelly.—Preliminary report on the iron ores and coal fields. Geological Survey of Missouri, 1872, 1-214. New York, 1873.

[38]Regis Chauvenet.—The iron resources of Colorado. Trans. Amer. Inst. Min. Eng., XVIII, 266-273. New York, 1890.

Texas.[39]

Iowa.[40]

Near Waukon, Iowa, in the Trenton formation. Ore is a secondary deposit partially and "bog iron ore" principally.

Wyoming.[41]

Large lenticular masses of red hematite in slate.

Utah.[42]

Magnetite and hematite in a belt twenty miles long at the contact of carboniferous limestone and eruptive miocene andesites.

Washington.[43]

The ores are primarily of sedimentary nature, were laid down on serpentines, are overlain by eocene sandstone, and have been considerably altered.

New Mexico.[44]

At Rio Grande are important deposits, but they are far from transportation.

The ore is hematite along the sides of dikes which cut carboniferous limestones. It has been formed by the filling of the shattered zone along the dikes by the settling of iron held in solution and derived from the weathered country rock.

Oregon.

There is a deposit at Oswego.

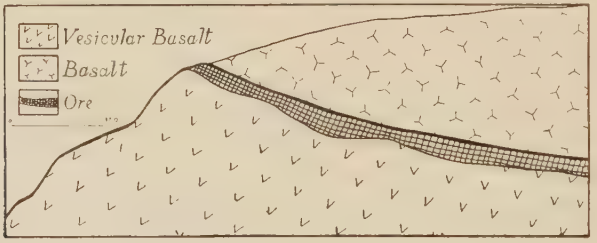

Fig. 32.—Section through the Prosser iron mine near Oswego, Oregon. (Putnam.)

[39]R. A. F. Penrose, Jr.—The iron ores of East Texas. First ann. rep. Geological Survey of Texas for 1889, 65-86. Austin, 1890.

E. T. Dumble.—The iron ores of East Texas. Engineering and Mining Journal, LXXII, 104. New York, 1901.

[40]S. W. Beyer.—Iowa's iron mine. Engineering and Mining Journal, LXXIII, 275-6. New York, 1902.

[41]H. M. Chance.—The iron mines of Hartville, Wyoming. Trans. Amer. Inst. Min. Eng., XXX, 987-1003. New York, 1901.

[42]C. K. Leith and E. C. Harder.—The iron ores of the Iron Springs district, Utah. Bul. 338, U. S. Geological Survey. Washington, 1908.

[43]G. O. Smith and Bailey Willis.—The Clealum iron-ores, Washington. Trans. Amer. Inst. Min. Eng., XXX, 356-366. New York, 1901.

[44]C. R. Keyes.—Iron deposits of the Chupadera mesa. Engineering and Mining Journal, LXXVIII, 632. New York, 1904.

Lindgren, Graton, and Gordon.—The ore deposits of New Mexico. Professional paper No. 68, U. S. Geological Survey. Washington, 1910.

Relative importance of the iron regions of the United States:

1. Lake Superior region; 2. Appalachian region; 3. Western region.

The principal iron ore producing states in the order of their importance in 1907 were: Minnesota, Michigan, Alabama, New York, Wisconsin, Pennsylvania, and Tennessee.

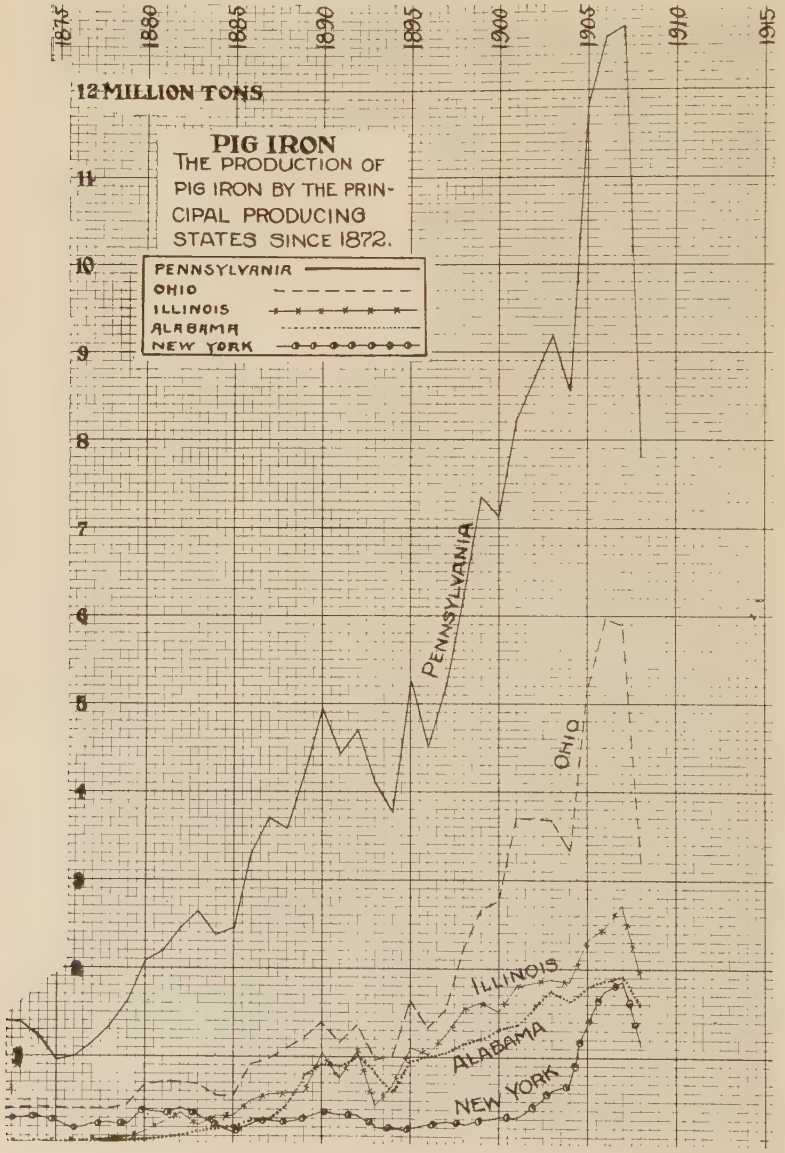

Fig. 33.—Chart showing the production of pig iron by states since 1872.

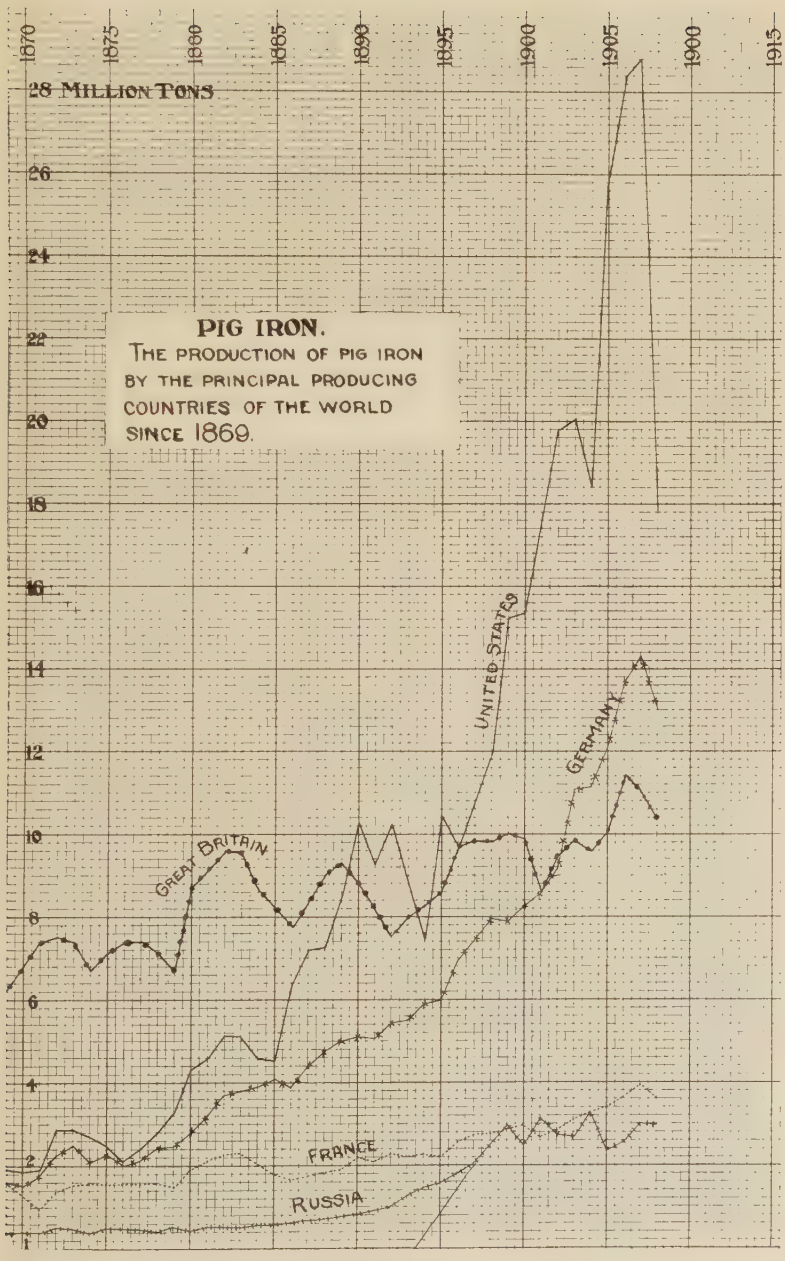
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
28 MILLION TONS
26
24
22
20
18
16
14
12
10
8
6
4
2
1
PIG IRON.
THE PRODUCTION OF PIG IRON BY THE PRINCIPAL PRODUCING COUNTRIES OF THE WORLD SINCE 1869.
UNITED STATES
GERMANY
GREAT BRITAIN
FRANCE
RUSSIA

Fig. 34.

GOLD[1]

Gold is a soft, dull yellow metal having a specific gravity of 19.33 when pure.

Uses.

Gold has been used from the earliest times for coins and for ornamental purposes.

Coinage; the stability in value of gold coin.[2]

Ornamental purposes; foil for gilding, dentistry, medicine, photography.

Ores.

Most of the gold mined is found as native gold; it is often alloyed with silver and other metals. California gold contains from 11 to 13 per cent of silver; Australian gold contains 5 per cent of silver.

The other gold bearing minerals are:

Sylvanite (Te 62.1, Au 24.5, Ag 14.4, variable).

Nagyagite (one analysis, Te 30.52, S 8.07, Pb 50.78, Au 9.11 + Ag and Cu. Other analyses yield: Te 15.11 up, S to 10.76, Pb to 57.16, Au 7.41 to 12.75.

Petzite (Au 25.5, Ag 42.00, Te 32.58, variable).

Modes of Occurrence and Association[3]

Geological distribution.[4]

Gold is found:

1. In veins, as free gold, and in combination.
   The gangue is generally quartz; exceptions.[5]

[1]A. Liversidge.—Contributions to the bibliography of gold. Proc. Austral. Assoc. Adv. Sci., VI, 240-256. Sydney (1896). (This contains titles not given in Locke's Gold.)

A. G. Locke.—Gold. London, 1882. (Bibliography.)

A. de Foville.—La géographie de l'or. Ann. de Géographie, 6me Anneé, 193-211. Paris, 1897.

Cumenge et Robellaz.—L'or dans la nature. Paris, 1898.

L. de Launay.—The world's gold: its geology, extraction, and political economy. New York, 1907.

Alex. Del Mar.—The history of the precious metals from the earliest times to the present day. 2nd ed. xxii + 480. New York, 1902.

[2]W. R. Ingalls.—Has the value of gold depreciated? Engineering and Mining Journal, LXXXVI, 1037-1042. New York, 1908.

[3]G. P. Merrill.—Gold and its associations. Engineering and Mining Journal, LXXIX, 992-993. New York, 1905.

[4]J. M. Maclaren.—Gold: its geological occurrence and geographical distribution. 687 + xxiii. London, 1908.

[5]W. P. Blake.—Gold in granite and plutonic rocks. Trans. Amer. Inst. Min. Eng., XXVI, 290-298. New York, 1897.

G. P. Merrill.—An occurrence of free gold in granite.—Amer. Journal of Science, CLI, 309-311. New Haven, 1896.

Mining vein deposits.

Milling,[6] concentrating.

The chlorination process is based upon the "property of chlorine gas to transform metallic gold into soluble chloride of gold." Gold must be metallic.[7] Sulphides must be roasted and all other metals must be converted to oxides.

The cyanide process is based upon the principle that a dilute solution of cyanide of potassium dissolves gold and silver.[8]

2. In stream or placer deposits, as flakes, grains, or nuggets.

Origin of placer gold.[9]

Beach deposits; stream deposits.

Geographic changes subsequent to their deposition.

The high Eocene terrace gravels of the Sierras.[10]

Rich placers are not necessarily derived from rich veins.

The origin of nuggets.[11]

The largest nugget ever found in California came from the Morgan mine, Calaveras county; it weighed 195 pounds, and was worth $43,534.

Methods of mining placer deposits.

Panning, sluicing, booming, dredging,[12] amalgamation.

Dry placers.[13]

The deep leads of Victoria.[14]

[6]E. B. Preston.—California gold mill practices. Bulletin 6, California State Mining Bureau. Sacramento, 1895.

[7]T. K. Rose.—The extraction of gold by chemical methods. Nature, LV, 448-9. London, 1897.

[8]A. Scheidel.—The cyanide process. Bulletin 5, California State Mining Bureau. Sacramento, 1894. (Reprinted, London, 1895.)

James Park.—The cyanide process of gold extraction. Auckland, New Zealand. Melbourne, 1896.

C. H. Fulton.—The cyanide process in the Black Hills of Dakota. Bul. 5, South Dakota School of Mines. Rapid City, 1902.

[9]H. L. Smyth.—The origin and classification of placers.—Engineering and Mining Journal, LXXIX, 1045-1046; 1179-1180; 1228-1230. New York, 1905.

[10]W. Lindgren.—The age of the auriferous gravels of the Sierra Nevada. Journal of Geology, IV, 881. Chicago, 1896.

[11]T. J. Henley.—Famous gold nuggets of the world. New York, 1900.

[12]Aug. J. Bowie, Jr.—Dredging for gold in southern river beds. Engineering and Mining Journal, LXIII, 211-212. New York, 1897.

Aug. J. Bowie, Jr.—A practical treatise on hydraulic mining in California. New York, 1893.

J. B. Jacquet.—Notes on gold dredging. Mineral Resources (of New South Wales), no. 3. Sydney, 1898.

Recent gold dredges. Engineering and Mining Journal, LXVI, 728-9. New York, 1898.

[13]H. A. Mather.—The problem of the dry placers. Engineering and Mining Journal, LXXVI, 314-315. New York, 1903.

[14]The deep beds of Victoria. Mining Magazine, XI, 139-143. Jan.-Feb., 1905.

Distribution.

Gold is one of the most widely distributed elements; it is found in rocks of all ages and kinds, and is even a constituent of sea water.[15]

Gold is found on the sea bottom.[16]

Gold sometimes occurs in shale in minute quantities.[17]

THE PRINCIPAL GOLD PRODUCING COUNTRIES.

	1898.	1908.
1. South Africa	$78,070,761	$145,819,016
2. United States	65,082,430	96,313,256
3. Australasia	62,294,481	72,509,200
4. Russia	24,734,418	30,944,561
5. Mexico	8,236,720	24,518,548
6. Rhodesia (Africa)	433,682	12,276,394
7. British India	7,765,807	10,424,067
8. Canada	13,700,000	9,559,274
9. West Coast (Africa)	720,248	5,773,544
10. China	6,641,190	5,165,000
11. Colombia (18)	3,700,000	3,514,073
12. Japan	790,826	3,203,850
13. Chile	1,240,000	3,100,000
14. Central America	505,096	2,273,875
15. Hungary	1,839,536	2,273,815

South African Deposits.[20]

Though long known, the gold deposits of the Transvaal have been worked only since 1886.[21]

[15]A. Liversidge.—Gold and silver in sea water. Jour. and Proc. Royal Society of New South Wales, XXIX, 335-349; 350-366. Sydney, 1896.

[16]Luther Wagoner.—The presence of gold and silver in deep sea dredgings. Trans. Amer. Inst. Min. Eng., XXXVIII, 704-705. New York, 1908.

[17]W. Lindgren.—Tests for gold and silver in the shales of western Kansas. Bul. 202, U. S. Geological Survey. Washington, 1902.

[18]M. A. Damangeon.—L'industrie aurifère en Colombie. 231 pages. Paris, 1907.

F. F. Sharpless.—Placer mining in Antioquia, Colombia. Engineering and Mining Journal, LXXIX, 994. New York, 1905.

[19]S. J. Truscott.—The mining and occurrence of gold in the Dutch East Indies. Engineering and Mining Journal, LXXIV, 444-445; 479-481. New York, 1902.

[20]S. Czyszkowski.—The deposition of gold in South Africa. American Geologist, XVII, 306-323. Minneapolis, 1896.

F. H. Hatch and J. A. Chalmers.—The gold mines of the Rand. 306. London and New York, 1895.

Theo. Reunert.—Diamonds and gold in South Africa. Johannesburg, 1893.

L. de Launay.—The Witwatersrand gold field and its working. Engineering and Mining Journal, LXIII, 631-632; 659-661. New York, 1897.

S. J. Truscott.—The Witwatersrand gold fields, banket and mining practice. London and New York, 1907.

L. de Launay.—Les mines d'or du Transvaal. Paris, 1896.

G. F. Becker.—Auriferous conglomerate of the Transvaal. American Journal of Science, V, 193-208. New Haven, 1898.

[21]J. H. Hammond and T. H. Leggett.—Gold mining in the Transvaal, South Africa. Trans. Amer. Inst. Min. Eng., XXXI, 817-855. New York, 1902.

The Rand.[22] The gold yield of the Witwatersrand fields increased from about $400,000 in 1887 to $145,819,016 in 1908.

Gold in quartz conglomerate beds, occasionally broken by faults and dikes.[23]

Simplicity of geologic structure as compared with other gold fields, to which is due the certainty of results.

Fig. 35.—Section through shafts in the Rand gold field showing the structure and continuation of the beds at great depths. (Hatch and Chalmers.)

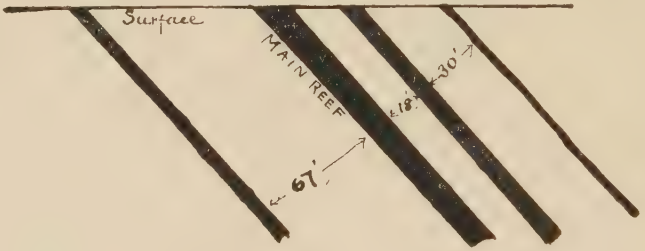

Fig. 36.—Section of the Glencairn property in the Rand, showing portions of the four reefs or bedded deposits. (Hatch and Chalmers.)

[22]R. A. F. Penrose, Jr.—The Witwatersrand gold region, Transvaal, South Africa, as seen in recent mining developments. Journal of Geology, XV, 735-749. Chicago, 1907.

J. W. Gregory.—The origin of the gold of the Rand goldfield. Economic Geology. IV, 118-129. 1909.

F. Hellmann. -Economic Geology, IV, 251-255. 1909.

G. A. Denny.—Economic Geology, IV, 470-485. 1909.

[23]L. de Launay.—Sur les caractères géologiques des conglomérats aurifères du Witwatersrand. Comptes Rendus, CXXII, 260-262; 343-346. Paris, 1896.

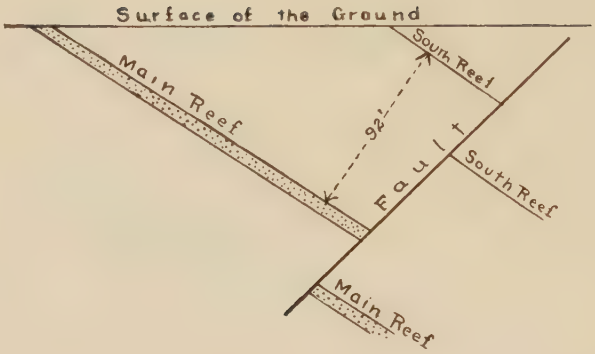

Fig. 37.—Section across the reefs of the Rand showing the faulting. (Hatch and Chalmers.)

Theories regarding the origin of the gold.

I. Mechanical accumulations in the gravels.

II. Introduction by solution.

Australasian Gold Fields.[24]

The gold producing colonies in the order of output.

Victoria.[25]

Placer gold is found in the Tertiary and Quaternary gravels at Ballarat and Bendigo.

New Zealand.[26]

Lode deposits occur at Aukland.

Fissure veins cut Tertiary eruptives near craters.

At Otago there are fissure veins and lenses in Paleozoic mica schist.

Placers of Recent, Pleistocene, Pliocene and Miocene ages produce three-fourths of the output of New Zealand.

[24]John R. Don.—The genesis of certain auriferous lodes. Trans. Amer. Inst. Min. Eng., XXVII, 564-668; 993-1003. New York, 1897.

K. Schmeisser.—The gold fields of Australasia. London, 1898.

H. C. Hoover.—Mining and milling gold ores in western Australia. Engineering and Mining Journal, LXVI, 725-726. New York, 1898.

L. Babu.—Les mines d'or de l'Australie. Annales des Mines, 9me sér. IX, 315-395. Paris, 1896.

L. Gascuel.—Notes sur les champs d'or de Coolgardie. Annales des Mines, 9me sér., XV, 205-231. Paris, 1899.

[25]W. Lindgren.—Mining the Australian deep leads. Mining Magazine, XI, 139-143. 1905.

[26]L. de Launay.—Les richesses minérales de la Nouvelle Zélande. Ann. des Mines, 9me sér., V, 523-554. Paris, 1894. (Bibliography.)

James Park.—The geology of New Zealand. 334-378. Melbourne and London, 1910.

New South Wales.[27]

The principal deposits are fissure veins and lodes in Silurian sediments and later igneous rocks.

Queensland, West Australia, Tasmania, and South Australia.

Veins and lodes are called "reefs."

"Saddle reefs" in the Bendigo fields of Victoria and in the Hargreaves fields of New South Wales.[28]

Gold in India.[29]

Recent and Pleistocene gravels of India have yielded placer gold for centuries.

No lodes or veins have been discovered.

Fig. 38.—Section across anticlinal and synclinal "saddle reefs" at Tambaroora, N. S. Wales. (Watt.)

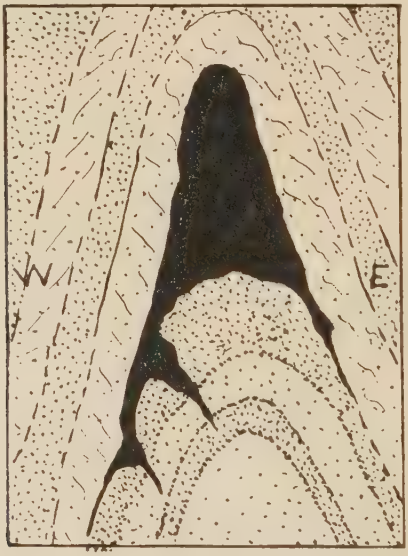

Fig. 39.—Section of a "saddle reef" or lode, New Chum Consolidated mine, Bendigo gold field, Victoria, Australia. (Rickard.)

[27]E. F. Pittman.—The mineral resources of New South Wales. 1-74. Sydney, 1901.

[28]T. A. Rickard.—The saddle reefs of Bendigo. Engineering and Mining Journal, LXXIII, 440-443. New York, 1902.

[29]V. Ball.—On the mode of occurrence and distribution of gold in India. Journal of the Royal Geological Society of Ireland, V, 258-280. Edinburgh, 1880. Ibid, VI, 201-206. 1881.

Fig. 40.—Section through the Bendigo gold fields, Victoria, Australia, showing the saddle reefs. (Rickard.)

Gold in Russia.[30]

There are gold-bearing post-Tertiary gravels on the south side of the Ural Mountains in Russia.

Gold in Canada.[31]

Gold regions of the United States.

The Appalachian region.

Gold was first discovered in the United States in 1799 in North Carolina. Between 1843 and 1848 the annual production was near $2,000,000.

Gold occurs in quartz veins, in slates, gneiss, and schists, and in the residual clays derived from these rocks. Rocks Archean or lowest Paleozoic.

Gold mined in Virginia, North Carolina,[32] South Carolina, and Georgia.[33]

P. Lake.—Origin of gold in India. Science, XXII, 121. New York, 1893.

[30]E. D. Levat.—The gold placers of Siberia. Engineering and Mining Journal, LXIII, 90. New York, 1897.

A. Keppen.—The industries of Russia. IV, Mining and Metallurgy. St. Petersburg, 1893.

H. B. C. Nitze.—The gold placers of the Eastern Oural Mts. Russia. Engineering and Mining Journal, LXVI, 305-306. New York, 1898.

[31]E. R. Faribault.—The gold measures of Novia Scotia. Ottawa, 1899.

A list of the publications of the Geological Survey of Canada on gold is given in the "General Index to the Reports of Progress, 1863-1884" at pages 189-191, 1900; a later list is given in the General Index to Reports 1885-1906, pages 365-368. Ottawa, 1908.

[32]H. B. C. Nitze and H. A. J. Wilkens.—Gold mining in North Carolina and adjacent south Appalachian regions. Bulletin 10, Geological Survey of North Carolina. Raleigh, 1897.

[33]Yeates, McCallie and King.—Gold deposits of Georgia. Bulletin 4, Geological Survey of Georgia, Atlanta, 1896.

William Tatham.—Gold mining in Georgia. Jour. Franklin Institute, CXLVI, 19-26. Philadelphia, 1898.

S. P. Jones.—Second report on the gold deposits of Georgia. Bul. 19, Geological Survey of Georgia. Atlanta, 1909.

E. C. Eckel.—The Dahlonega gold district of Georgia. Engineering and Mining Journal, LXXV, 219-220. New York, 1903.

The Rocky Mountain District.

Colorado.[34]

Gilpin county: gold with pyrites in fissure veins through gneiss.

Boulder county: gold as telluride ores, in small veins, along fault planes, in granite or geniss, associated with porphyry.

Clear Creek county: gold in fissure veins through granite rocks.

Lake county: the Leadville district is in this county; the gold is in limestone associated with porphyry, in porphyry dikes, in veins through granite, and in placers.

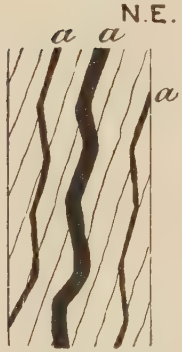

Fig. 41.—Section in the Victor, Smuggler Lee, and Buena Vista mines, showing the parallel ore-bodies. (a.) (Penrose.)

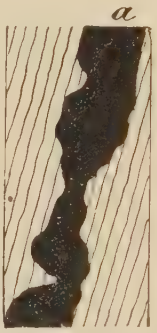

Fig. 42.—Section showing the form of the ore-body in the Victor, Smuggler Lee, and Buena Vista mines, Cripple Creek district, Colorado. (Penrose.)

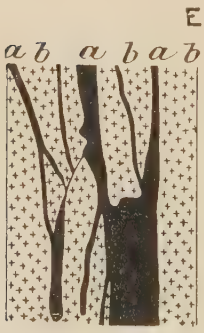

Fig. 43.—Section showing the forms of the vein in the Blue Bird mine, Cripple Creek district. The ore is shown black; *b* is the country rock (Penrose.)

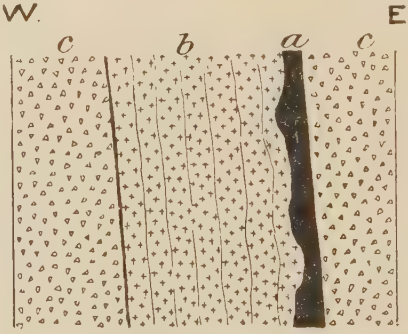

Fig. 44.—Section in the Elkton mine, Cripple Creek district, Colorado, showing the relation of the vein *a* to the dike *b* and to the country rock *c*. (Penrose.)

[34]Arthur Lakes.—Geology of Colorado and western ore deposits. Denver, 1893.

Fig. 45.—Vertical section showing the forking of the Pike's Peak vein, Cripple Creek district, Colorado. (Penrose.)

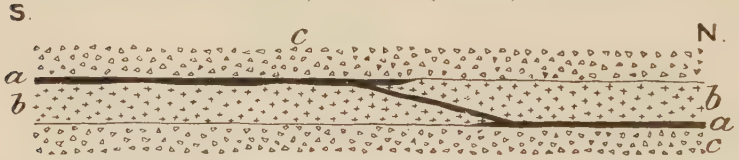

Fig. 46.—Horizontal section in the Elkton mine, Cripple Creek district, Colorado, showing the relation of the vein *a* to the dike *b* and to the country rock *c*. (Penrose.)

Teller county: the Cripple Creek region;[25] ore native gold and tellurides in fissures and associated with dikes. The country rocks are eruptives.

San Miguel county: Telluride district.[36] Fissures in eruptive rocks

[35]W. Cross and R. A. F. Penrose, Jr.—Geology and mining industries of the Cripple Creek district, Colorado. Sixteenth ann. rep. U. S. Geological Survey, pt. II, 1-209. Washington, 1895.

W. Lindgren and F. L. Ransome.—Geology and gold deposits of the Cripple Creek District, Colorado. Professional Paper 54, U. S. Geological Survey. Washington, 1906.

T. A. Rickard.—The lodes of Cripple Creek. Trans. Amer. Inst. Min. Eng. XXXIII, 578-618. New York, 1903.

[36]C. W. Purington.—Preliminary report on the mining industries of the Telluride quadrangle, Colorado. Eighteenth ann. rep. U. S. Geological Survey, pt. III, 751-848. Washington, 1898.

of late Tertiary age have been filled with native gold and gold telluride by precipitation from solutions.

Empire, Silver Plume, and Georgetown districts.[37] East and west fissures in Paleozoic granite have been filled with sphalerite and crossed by north and south fissures which are filled with galena, pyrite, and gold.

Aspen district.[38] Solutions have deposited rich sulphides along fissures, faults, and fault zones of post-Cretaceous age in Carboniferous sedimentary rocks. Silver is the principal product.

Wyoming and South Dakota: the Black Hills region.

Gold in schists, in Cambrian sandstones, in segregation veins, and in placers of Pleistocene age.

Montana.

Silver Bow county: gold in placers near Butte.

Deer Lodge county: gold in placers and quartz veins; also in granite, where silver in large quantities is often associated with it.

Lewis and Clarke county: gold in placers, near Helena, and in quartz veins through granite and slate.

Fergus county: gold chiefly in deposits associated with igneous rocks.[39]

Cascade county:[40] silver, lead, copper sulphides carrying gold, occur along northeast-southwest fissures which cut Archean gneiss, schist, and later igneous dikes.

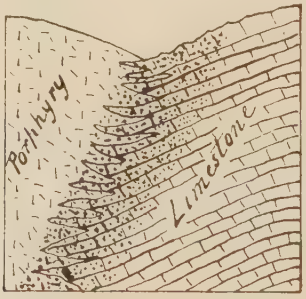

Fig. 47.—Diagrammatic section showing the contact of porphyry and limestone and the zone of ore deposition, Maginnis mine, Judith Mountains, Montana. (Weed and Pirsson.)

[37]J. E. Spurr, G. H. Garrey and S. H. Ball.—Economic geology of the Georgetown quadrangle, and Empire district, Colorado. Professional Paper 63, U. S. Geological Survey. Washington, 1908.

[38]J. E. Spurr.—Geology of the Aspen mining district, Colorado. Monograph, XXXI, U. S. Geological Survey. Washington, 1898.

[39]W. H. Weed and L. V. Pirsson.—Geology and mineral resources of the Judith mountains of Montana. Eighteenth ann. rep. U. S. Geological Survey, pt. III, 437-616. Washington, 1898.

[40]W. H. Weed.—Notes on the ore deposits of the Little Belt Mts., Montana. 20th ann. rep. U. S. Geological Survey, pt. III, 401-446. Washington, 1900.

Jefferson county: the Elkhorn mine and district.[41]

Idaho.[42]

Boise county: placers developed in 1863.

Alturas county: gold associated with silver in quartz veins.

Shoshone county:[43] Coeur d'Alene district has gold associated with silver and lead in fissures as veins and lodes.

Fig. 48.—Generalized sketch showing vein structure in the Coeur d'Alene district, Idaho. (Ransome and Calkins.)

The Great Basin Region.

Utah.

Salt Lake county: in Bingham Canyon gold is associated with silver in bedded quartz veins.

Mercur district:[44] in the Oquirrh Range. Gold (probably originally deposited as telluride) where altered by weather occurs native and as tellurides, in altered limestones, mostly along the under side of thin intruded porphyry sheets, but sometimes in the porphyries themselves, and in the limestones immediately above them. The ores were deposited along fracture planes.

[41]W. H. Weed.—Geology and ore deposits of the Elkhorn mining district, Jefferson county, Montana. 22d ann. rep. U. S. Geological Survey, pt. II, 399-510. Washington, 1901.

[42]W. Lindgren.—The mining districts of the Idaho basin and the Boise ridge, Idaho. Eighteenth ann. rep. U. S. Geological Survey, pt. III, 617-719. Washington, 1898.

[43]F. L. Ransome and C. A. Calkins.—The geology and ore deposits of the Coeur d'Alene mining district, Idaho. Professional Paper 62, U. S. Geological Survey. Washington, 1908.

W. Lindgren.—The gold and silver veins of Silver City, De Lamar and other mining districts in Idaho. 20th ann. rep. U. S. Geological Survey, pt. III, 65-256. Washington, 1900.

[44]J. Edward Spurr.—Economic geology of the Mercur mining district. Sixteenth ann. rep. U. S. Geological Survey, pt. II, 343-455.

The rocks of the locality are Lower and Upper Carboniferous sandstones and limestones, aggregating 12,000 feet in thickness; they are exposed along a low anticlinal arch. (Spurr.)

Nevada.[45]

White Pine county: Egan Canyon; gold with silver occurs in quartz veins traversing slate.

The Comstock lode:[46] gold and silver, in a great quartz vein, with country rock of diorite and diabase. Ore in rich masses called bonanzas. Proportion of gold to silver, 2:3.

Tonopah district:[47] the rocks are Tertiary volcanics. The most im-

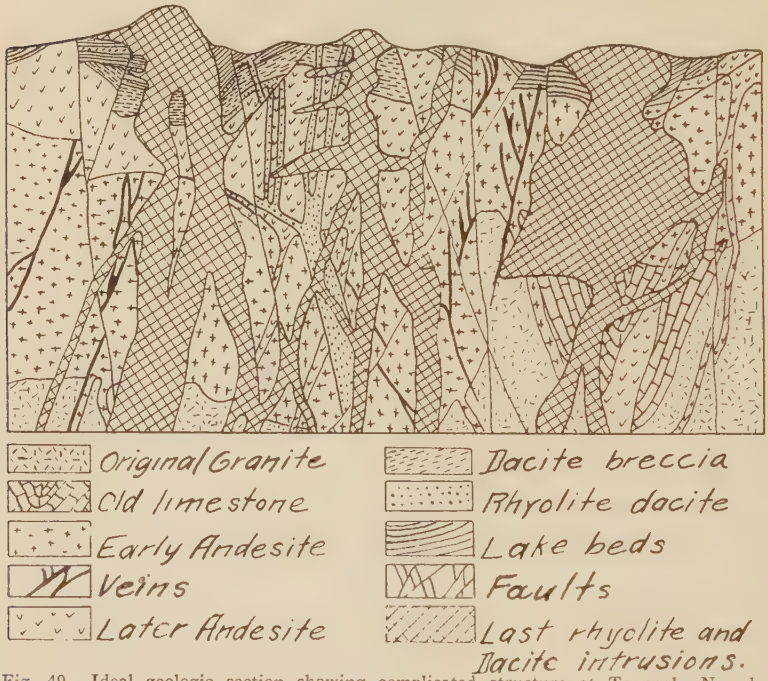

Fig. 49.—Ideal geologic section showing complicated structure at Tonopah, Nevada. (Spurr.)

[45]J. E. Spurr.—Genetic relations of the western Nevada ores. Trans. Amer. Inst. Min. Eng., XXXVI, 372-402. New York, 1906.

[46]G. F. Becker.—Geology of the Comstock lode and the Washoe district. Monograph III, U. S. Geological Survey. Washington, 1882.

E. Lord.—Comstock mining and miners. Monograph IV, U. S. Geological Survey. Washington, 1883.

[47]J. E. Spurr.—Geology of the Tonopah mining district, Nevada. Professional Paper 42, U. S. Geological Survey, Washington, 1905.

J. E. Spurr.—Developments at Tonopah, Nevada during 1904. Bul. 260, U. S. Geological Survey, 140-149. Washington, 1905.

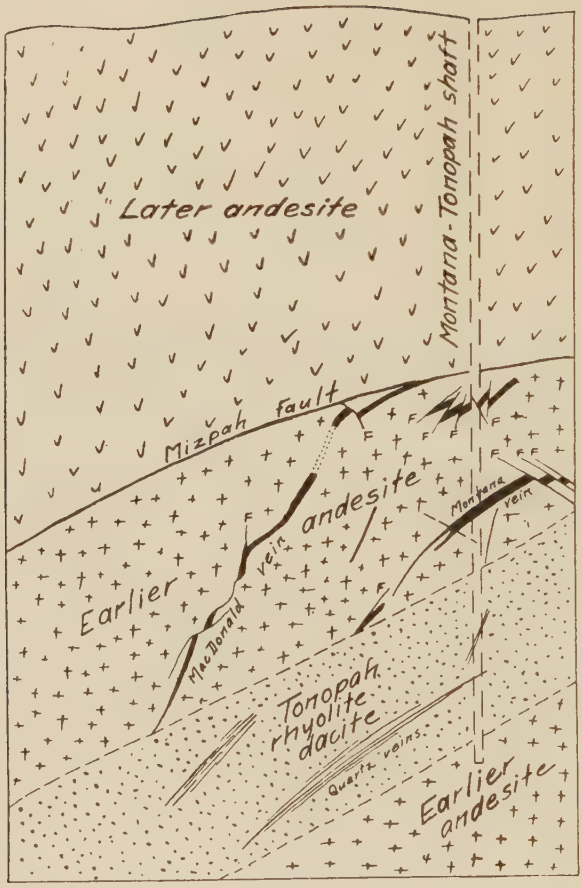

Fig. 50.—Section showing the geology of the Montana-Tonopah mine, Tonopah, Nevada. (Spurr.)

portant mineral veins are in early andesites. The minerals are oxidized near the surface. Two other series of veins occur; one in dacite, and another in rhyolite.

At Goldfield[48] native gold is associated with a great variety of sul-

[48]F. L. Ransome.—The geology and ore deposits of Goldfield, Nevada. Professional Paper 66, U. S. Geological Survey. Washington, 1909.

J. B. Hastings and C. P. Berkey.—The geology and petrography of the Goldfield mining district, Nevada. Trans. Amer. Inst. Min. Eng., XXXVII, 140-159. New York, 1907.

phides in branching veins and rich irregular lodes in late Tertiary dacite.

The ores are more or less altered near the surface.

At Blair[49] crystalline, auriferous quartz occurs in lenses in metamorphosed slaty Paleozoic limestone and Tertiary alaskite.

At Bullfrog quartz bearing gold occurs along fault zones in Tertiary eruptives similar to those of Goldfield and Tonopah.

Other producing districts in Nevada are Searchlight, Bullfrog, Manhattan, Ely, Rhyolite, and Kawich.

The Pacific Slope Region.

California.[50]

Gold occurs:

In quartz veins in slates of Devonian and Carboniferous ages, but mostly in Triassic and Jurassic[51] slates and schists.

In placers derived from the quartz veins.

River gravels[52] are usually shallow and recent.

High gravels.

Origin and age of the high gravels.[53]

Some of them are covered by volcanics of Miocene age.

[49]J. E. Spurr.—Ore deposits of the Silver Peak quadrangle, Nevada. Professional Paper 55, U. S. Geological Survey. Washington, 1906.

[50]California mines and minerals. Published by the California Miners' Association. San Francisco, 1899.

[51]W. Lindgren.—Characteristic features of California gold quartz veins. Bulletin of the Geological Society of America, VI, 221-240. 1895.

H. W. Turner.—Gold ores of California. American Journal of Science, CXLIX, 374-379. New Haven, 1895.

W. Lindgren.—The gold quartz veins of Nevada City and Grass Valley districts, California. Seventeenth ann. rep. U. S. Geological Survey, pt. II, 1-262. Washington, 1896.

[52]J. D. Whitney.—The auriferous gravels of the Sierra Nevada of California. (Cambridge), 1880.

J. Ross Browne.—Mineral resources of the United States and Territories west of the Rocky Mountains. Washington, 1868.

R. E. Brown.—Ancient river beds of the Forest Hill divide. 10th ann. rep. State Min. 435-465. Sacramento, 1890; also 2nd Rep. 133-190. Sacramento, 1882.

J. H. Hammond.—The auriferous gravels of California. 9th ann. rep. State Mineralogist for 1889, 105-138. Sacramento, 1890.

H. W. Turner.—Auriferous gravels of the Sierra Nevada. American Geologist, XV, 371-379. Minneapolis, 1895.
The geology of the gold regions of California is shown on U. S. Geological Survey folios: 3, Placerville; 5, Sacramento; 11, Jackson; 15, Lassen Peak; 17, Marysville; 29, Nevada City; 37, Downieville; 41, Sonora; 51, Big Trees.

[53]J. Le Conte.—The old river beds of California. American Journal of Science, CXIX, 176-190. New Haven, 1880.

W. H. Storms.—Ancient channel system of Calaveras county. 12th ann. rep. Cal. State Mineralogist, 482-492. Sacramento, 1894.

H. G. Hanks.—The deep auriferous gravels and Table Mt., California. San Francisco, 1901.

W. Lindgren.—The age of the auriferous gravels of the Sierra Nevada. Journal of Geology, IV, 881-906. Chicago, 1896.

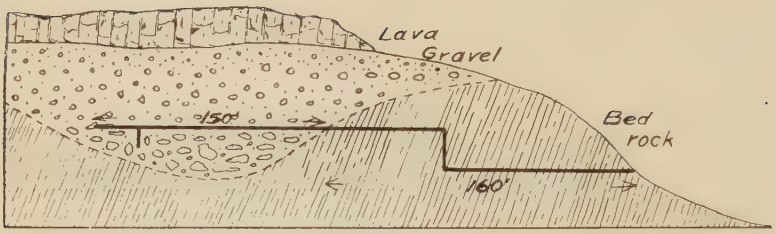

Fig. 51.—Cross-section at Pearl s Hill, California, showing auriferous gravels beneath lava. (Whitney.)

Extent of the California gold fields.

"The mother lode."[54] is 112 miles long, extending through Mariposa, Tuolumne, Calaveras, Amador, and El Dorado counties.

Methods of mining.

Quartz mining.

Hydraulic mining.[55]

Nine-tenths of California's gold has come from placer mines. Gravels workable by ordinary hydraulic process are now mostly exhausted, and all mining is quartz mining, while the gravels which were not available for ordinary hydraulic mining are now being worked by dredges.

Dredging.[56]

Oregon.[57]

Gold is found in quartz veins and placers, as in California.

At Port Orford gold occurs in beach sands.

Bohemia region of western Oregon.[58]

Quartz veins carrying gold and sulphides occur in igneous rocks of Miocene age.

[54]H. W. Fairbanks.—Geology of the Mother Lode gold belt. American Geologist, VII, 209-222. Minneapolis, 1891. Tenth ann. rep. State Mineralogist (of California), 23-90. 1890. Engineering and Mining Journal, LXII, 248-250. New York, 1896.

F. L. Ransome.—Geology of the Mother Lode district, Calif. Folio 63, U. S. Geological Survey. Washington, 1900.

[55]W. E. Thorne.—Notes on the cost of hydraulic mining in California. Trans. Amer. Inst. Min. Eng., XXXIII, 138-141. New York, 1903.

[56]J. E. Doolittle.—Gold dredging in California. Bul. 36, California State Mining Bureau. Sacramento, 1905.

G. P. Grimsley.—Gold dredging operations in California. Engineering and Mining Journal, LXXI, 823-824. New York, 1901; LXXII, 11 and 40-41. New York, 1901.

N. B. Knox.—Dredging at Oroville. Engineering and Mining Journal, LXXVI, 318. New York, 1903.

[57]W. Lindgren.—The gold belt of the Blue Mts. of Oregon. 22nd ann. rep. U. S. Geological Survey, pt. II, 551-776. Washington, 1901.

[58]J. S. Diller.—Bohemia mining region of western Oregon. 20th ann. rep. U. S. Geological Survey, pt. III, 1-36. Washington, 1900.

Washington.[59]

Placer gold occurs in Pleistocene gravels in the beds of rivers.

Veins of quartz and calcite carrying free gold occur on the sides of dikes cutting Cretaceous and Tertiary beds.

The Southwest.

Arizona.[60]

Quartz veins cut Paleozoic limestones, granites, and porphyry.

New Mexico.[61]

Placer gold occurs in the Rio Grande river bottom at Apache Canyon.

Alaska.[62]

Placer deposits[63] and quartz veins.

Placer deposits occur at a great many places: Seward Peninsula, Rampart region, Porcupine river.

The Yukon and Klondike region.[64]

Cape Nome beach placers.[65]

Gulch, bar, beach, tundra, and bench placers.

The Juneau district.

[59]I. C. Russell.—Geology of the Cascade Mts. in northern Washington. 20th ann. rep. U. S. Geological Survey, pt. II, 206-210. Washington, 1900.

[60]J. H. Pratt.—Gold deposits of Arizona. Engineering and Mining Journal, LXXIII, 795-796. New York, 1902.

J. A. Church. The Tombstone, Arizona, mining district. Trans. Amer. Inst. Min. Eng., XXXIII, 3-37. New York, 1902.

[61]Chas. R. Keyes.—Geology of the Apache Canyon placers, New Mexico. Engineering and Mining Journal, LXXVI, 966-967. New York, 1903.

Lindgren, Graton, and Gordon.—The ore deposits of New Mexico. Professional Paper 68, U. S. Geological Survey. Washington, 1910.

[62]J. E. Spurr.—Geology of the Yukon gold district, Alaska. Eighteenth ann. rep. U. S. Geological Survey, pt. III, 87-392. Washington, 1898.

G. F. Becker.—Reconnaissance of the gold fields of southern Alaska. Eighteenth ann. rep. U. S. Geological Survey, pt. III, 1-86. Washington, 1898.

R. A. F. Penrose, Jr.—Present condition of gold mining in Arctic America. Engineering and Mining Journal, LXXVI, 807-8; 852-3. New York, 1903.

[63]L. M. Prindle.—The gold placers of Forty Mile, Birch Creek, and Fairbanks regions, Alaska. Bul. 251, U. S. Geological Survey. Washington, 1905.

C. W. Purington.—Methods and costs of gravel and placer mining in Alaska. Bul. 243, U. S. Geological Survey. Washington, 1905.

[64]R. G. McConnell.—Preliminary report on the Klondike gold fields, Yukon district, Alaska. Geological Survey of Canada, XII, 16a-52a. Ottawa, 1902.

[65]Ivan Brostrom.—The new gold fields at Cape Nome, Alaska. San Francisco, 1899.

F. C. Schrader.—The Cape Nome gold district. National Geographic Magazine, XI, 15-23. Washington, 1900.

P. F. Travers.—Engineering and Mining Journal, LXVIII, 727. New York, 1899.

J. P. Hutchins.—Dredging beach gravel deposits near Nome. Engineering and Mining Journal, LXXXIV, 955-961. New York, 1907.

J. P. Hutchins.—Dredging beach gravel deposits near Nome. Engineering and Mining Journal, LXXXIV, 955-961. New York, 1907.

F. C. Schrader and A. H. Brooks.—Some notes on the Nome Gold region of Alaska. Trans. Amer. Inst. Min. Eng., XXX, 236-247. New York, 1901.

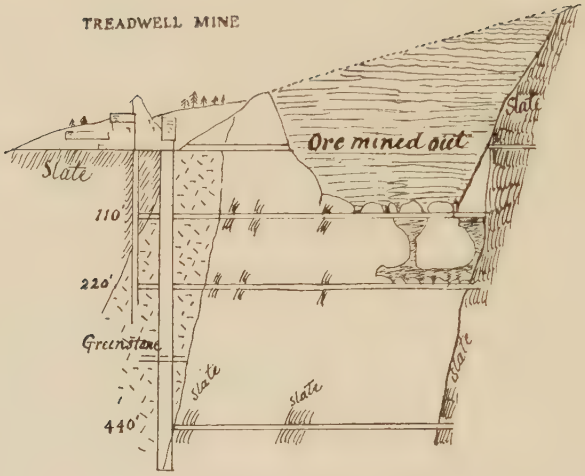

Fig. 52.—Section through the Alaska-Treadwell mine, Douglas Island, near Juneau, Alaska.

Effect of silver legislation on gold production.

The output of the leading gold producing states:

Statistics:[66]

[66]S. F. Emmons and G. F. Becker.—Statistics and technology of the precious metals. Tenth Census, XIII. Washington, 1885.

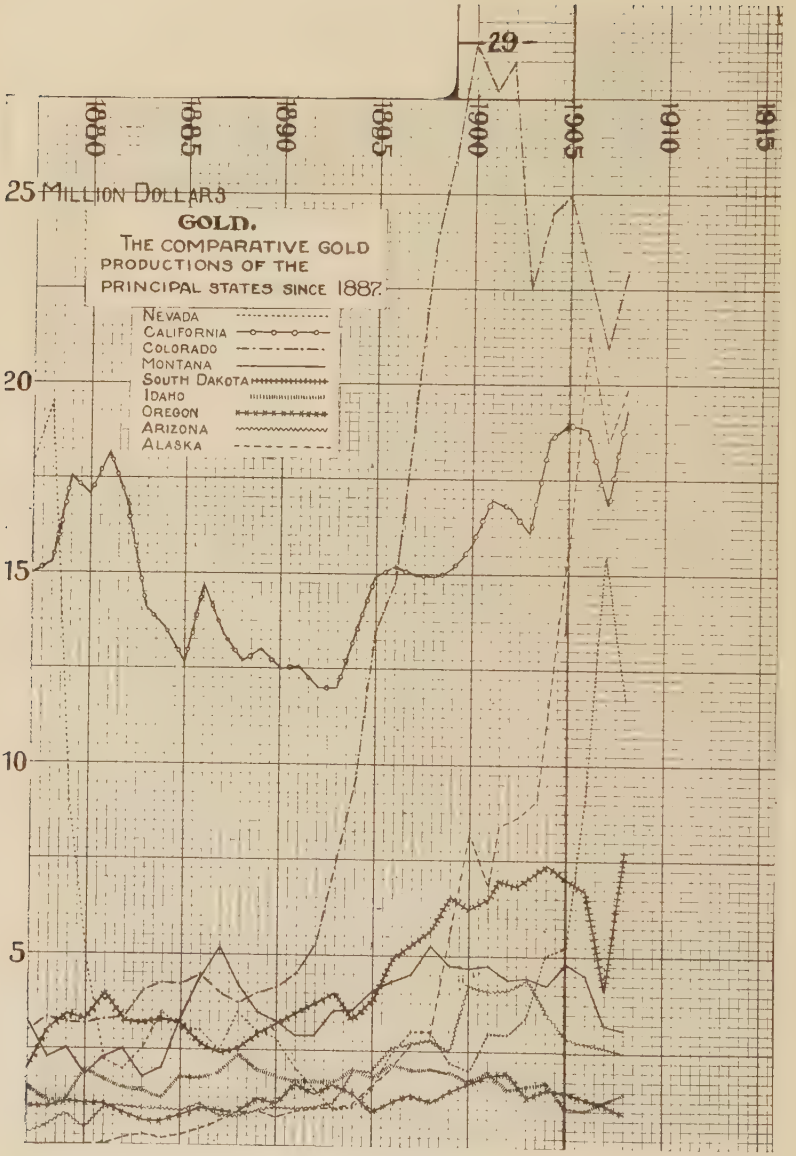
29
1880
1885
1890
1895
1900
1905
1910
1915
25 MILLION DOLLARS
GOLD.
THE COMPARATIVE GOLD PRODUCTIONS OF THE PRINCIPAL STATES SINCE 1887.
NEVADA
CALIFORNIA
COLORADO
MONTANA
SOUTH DAKOTA
IDAHO
OREGON
ARIZONA
ALASKA
20
15
10
5

Fig. 53.

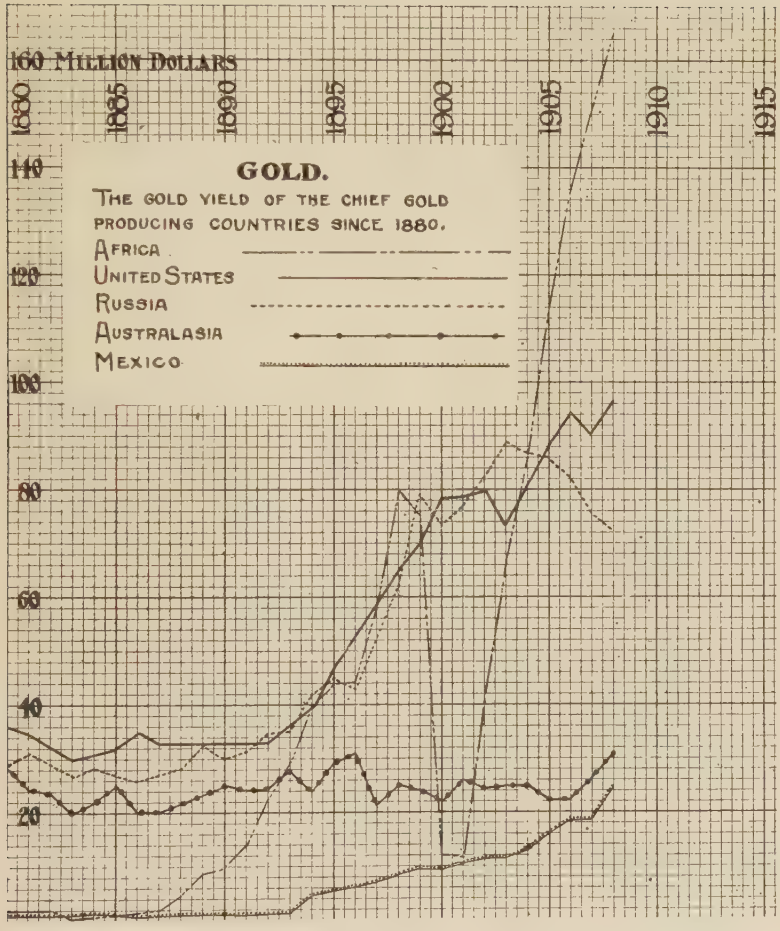
160 Million Dollars
140
120
100
80
60
40
20
1880
1885
1890
1895
1900
1905
1910
1915
GOLD.
The gold yield of the chief gold producing countries since 1880.
Africa
United States
Russia
Australasia
Mexico

Fig. 54.

SILVER.

Silver is a rather soft, metallic-white metal of 10.5 specific gravity.

Uses.

Coinage; alloys; tableware; jewelry; ornamental purposes; photography; medicine.

Ores.

Native silver (usually an alloy with copper, gold, or bismuth).

Argentite. Silver glance (Ag_2S), (Ag 87.1, S 12.9).

Pyrargyrite. Ruby silver (Ag_3SbS_3 or $3\,Ag_2SSb_2S_3$), (Ag 59.8, Sb 22.5, S 17.7).

Proustite. Light ruby silver. ($3\,Ag_2S$, As_2S_3 or Ag_3AsS_3), (Ag 65.5, As 15.1, S 19.4).

Stephanite. Brittle silver; black silver (Ag_5SbS_4 or $5\,Ag_2S\,Sb_2S_5$), (Ag 68.5, Sb 15.3, S 16.2).

Cerargyrite. Horn silver, silver chloride (Ag 75.3, Cl 24.7).

Bromyrite (Ag 57.4, Br. 42.6).

Embolite (49 per cent AgBr to 51 per cent Ag Cl).

Argentiferous galena (lead and silver in varying proportions).

Argentiferous tetrahedrite, or freibergite, a sulphide of copper and antimony, contains varying proportions of silver.

Relative importance of the different ores.

Occurrence and Association.

Most of the silver comes from argentiferous galena, but it is generally accompanied by copper and gold.

The rocks may be either sedimentary or igneous, and are frequently much folded, faulted, and altered by igneous intrusions.

The ore bodies sometimes occur as veins, sometimes as replacements, and sometimes as contact deposits.

Distribution.

Geologic.

Silver occurs in rocks of all ages.

Geographic.

Silver has a very general geographic distribution; there are but few countries that do not have it in some quantity.

In 1908 the leading silver yielding countries in the order of their production were Mexico, the United States, and Canada. These countries produce 75 per cent of the world's output.

Mexico.[1]

Canada.

Cobalt,[2] Ontario, is one of the most remarkable silver mining districts in the world.

The ores are native silver and silver sulphide, associated with nickel, cobalt, and copper. They originate in diabase dikes and are precipitated from solution in veins along joints and fissures and also impregnate Huronian sedimentaries.

Australasia, Peru,[3] Bolivia,[4] Germany, Spain, Japan, Central America, Africa, Austria-Hungary, Colombia, Chile.[5]

Silver in the United States.

The silver of the United States comes almost entirely from the region west of the Mississippi river. Colorado, Montana, Utah, Nevada, and Idaho produced 88 per cent of the total output in 1908.

Colorado.[6]

Leadville.[7]

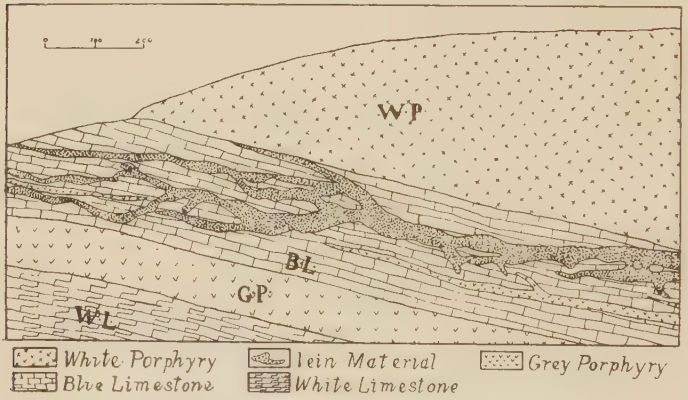

Fig. 55.—Section on the "gold ore chute" of Iron Hill, Leadville, Colorado. (Blow.)

[1]R. A. y Santillan.—Bibliography of Mexican geology and mining. Trans. Amer. Inst. Min. Eng., XXXII, 605-680. New York, 1902.

R. A. y Santillan.—Bibliografia geologica y minera de la Republica Mexicana. Mexico, 1908.

[2]H. C. George.—The Nipissing mine, Cobalt, Ontario. Engineering and Mining Journal, LXXXII, 967-8. New York, 1906.

R. E. Hore.—Ores and rocks of the Cobalt region. Canadian Mining Journal, new series, I, 300-301. Toronto, 1908.

[3]A. D. Hodges, Jr.—Notes on.....the geology of the Cerro de Pasco, Peru. Trans. Amer. Inst. Min. Eng., XVI, 729-753. New York, 1888.

[4]A. F. Wendt.—The Potosí, Bolivia, silver-district. Trans. Amer. Inst. Min. Eng., XIX, 74-107. New York, 1891.

[5]Don Guillermo Yunge.—Estadística minera de Chile en 1903. I, 22-24. Santiago, 1905.

[6]Arthur Lakes.—Geology of Colorado and western ore deposits. Denver, 1893.

[7]S. F. Emmons.—Geology and Mining industry of Leadville, Colorado. Monograph XII, U. S. Geological Survey. Washington, 1886.

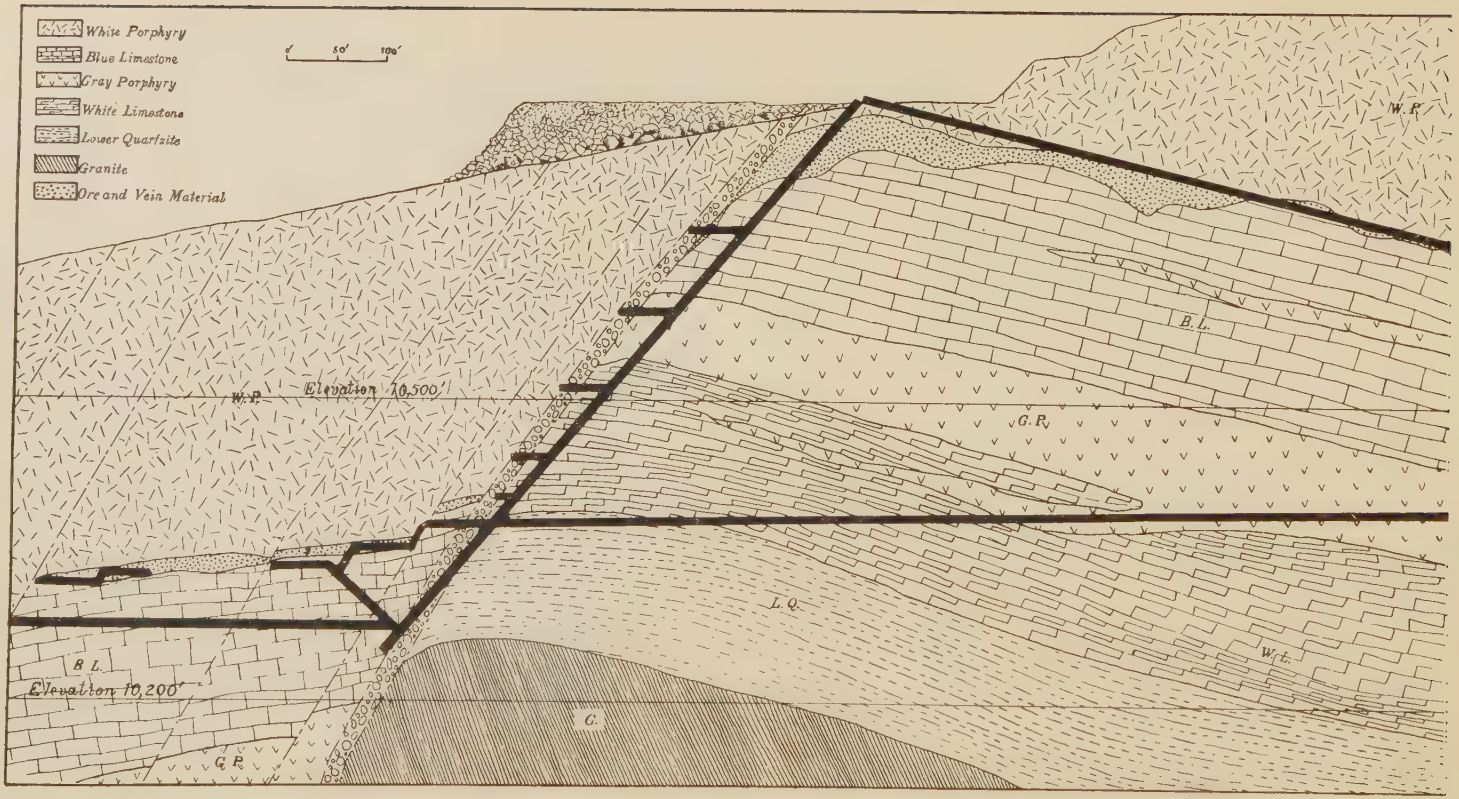

Fig. 56.—East-west section through the McKeen shaft, Leadville, Colorado, showing the faulted ore-bodies along the contacts. (Blow.)

Discovery made in 1874; prominent in 1877; output largest in 1892.
Ores: oxidized lead-silver, passing into sulphides at depths in faulted Carboniferous limestones.

Aspen.[8]

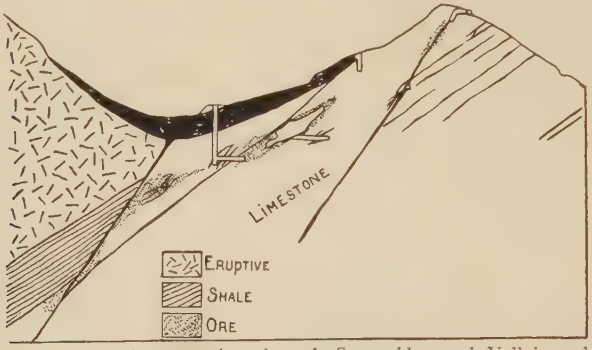

Fig. 57.—Northwest-southeast section through Spar ridge and Vallejo gulch, in the Aspen district, Colorado. Washington shaft is shown near Vallejo gulch.

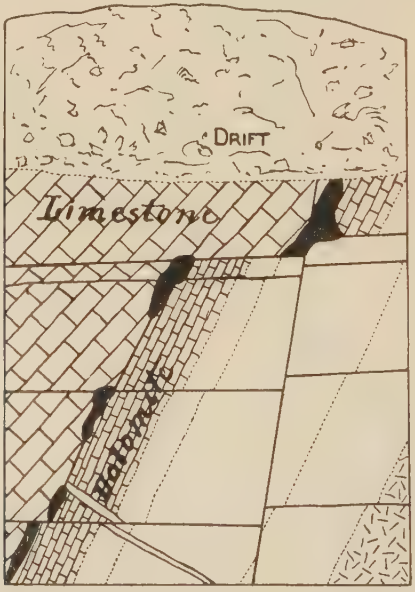

Fig. 58.—Section showing faults and ore-bodies in the Bushwhacker-Park Regent mine, Aspen, Colorado. (Spurr.)

Ores: oxidized lead-silver, in highly folded and faulted Carboniferous limestones.

[8]J. E. Spurr—Geology of the Aspen mining district, Colorado. Monograph XXXI, U. S. Geological Survey. Washington, 1898.

Creede.

Ores: oxides in fissure veins in igneous rocks.

Cripple Creek.[9]

Other Colorado districts: Eagle River, Ten Mile, Monarch, Rico,[10] Red Mountain, Custer county,[11] Silverton,[12] Empire.[13]

Montana.

Butte City region.[14]

Ores: native silver and galena in veins with quartz gangue containing some Mn; country rock of granite.

Granite Mountain.

Ores: ruby silver associated with gold in veins in gray granite.

Other Montana silver regions are: Cook City, Flint Creek, Glendale, and Elkhorn district.[15]

Utah.

Big and Little Cottonwood Canyons.

Ores: oxidized lead-silver, in bedded veins in Carboniferous limestones.

Beaver county.

Oxidized lead-silver ores occur in contact fissures (Horn Silver mine); in chambers in limestones (Cave mine); in fissure veins (Carbonate mine).

Summit county.

Ores in veins through quartzite (Ontario mine).

Other silver regions of Utah are Bingham Canyon, the Mercur district,[16] the Tintic district,[17] and Silver Reef.

[9]W. Cross and R. A. F. Penrose, Jr.—Geology and mining industries of the Cripple Creek district, Colorado. Sixteenth ann. rep. U. S. Geological Survey, pt. II, 1-209. Washington, 1895.

[10]F. L. Ransome.—The ore deposits of the Rico mountains, Colorado. 22nd ann. rep. U. S. Geological Survey, pt. II, 229-397. Washington, 1901.

[11]S. F. Emmons.—The mines of Custer county, Colorado. Seventeenth ann. rep. U. S. Geological Survey, pt. II, 405-472. Washington, 1896.

[12]F. L. Ransome.—A report on the economic geology of the Silverton quadrangle, Colorado. Bul. 182, U. S. Geological Survey. Washington, 1901.

[13]J. E. Spurr and G. H. Garrey.—Economic geology of the Georgetown quadrangle, Colorado. Professional Paper 63, U. S. Geological Survey. Washington, 1908.

[14]W. P. Blake.—Silver-mining and milling at Butte, Montana. Trans. Amer. Inst. Min. Eng., XVI, 38-45. New York, 1888.

S. F. Emmons.—Notes on the geology of Butte, Montana. Trans. Amer. Inst. Min. Eng., XVI, 49-62. New York, 1888.

[15]W. H. Weed.—Geology and ore deposits of the Elkhorn mining district, Jefferson county, Montana. 22nd ann. rep. U. S. Geological Survey, pt. II, 399-510. Washington, 1901.

[16]Spurr and Emmons.—Economic geology of the Mercur mining district, Utah. Sixteenth ann. rep. U. S. Geological Survey, pt. II, 343-455. Washington, 1895.

[17]G. W. Tower, Jr., and G. O. Smith.—Geology and mining industry of the Tintic district, Utah. 19th ann. rep. U. S. Geological Survey, pt. III, 601-767. Washington, 1899.

Nevada.

The Comstock lode[18] is a great fissure vein, four miles long, several hundred feet broad, with branching ends; it follows a fault line; the greatest displacement is at the centre, where it is nearly 3,000 feet. The mines reach a depth of about 3,000 feet, and there are more than 180 miles of workings.

Ores: high grade, associated with gold.
Silver is to gold as 3 to 2.

Yield has been over $132,000,000 in silver alone.

Ores in bodies irregularly distributed through the quartz gangue; bonanzas.
The country rock is diorite and diabase.

The Eureka district.[19]
Ores: oxidized lead-silver, with some gold irregularly distributed through veins in often brecciated Cambrian limestones and shales. Depth of alteration of ores over 1,300 feet.

The Tonopah district[20] was discovered in 1900.
During 1908, 75 per cent of the silver produced in Nevada came from Tonopah.

Silver sulphides occur with many rare materials in veins. The minerals are supposed to have originated by solfataric and fumarolic action during a period of Tertiary vulcanism. Oxidation by underground waters has taken place in the upper portions of the veins.

The Goldfield district[21] was discovered in 1902.
Primarily a gold district.
The minerals are sulphides, carbonates, and oxides with gold and copper.

Ores originate from the precipitation of sulphides in fissures resulting from intrusive masses of Tertiary dacite which carried precious metals in their magmas.

[18]G. F. Becker.—Geology of the Comstock lode and the Washoe district. Monograph III, U. S. Geological Survey. Washington, 1882.
E. Lord.—Comstock mining and miners. Monograph IV, U. S. Geological Survey. Washington, 1883.

[19]J. S. Curtis.—Silver-lead deposits of Eureka, Nevada. Monograph VII, U. S. Geological survey. Washington, 1884.
Arnold Hague.—Geology of the Eureka district, Nevada. Monograph XX, U. S. Geological Survey. Washington, 1892.

[20]J. E. Spurr.—Geology of the Tonopah mining district, Nevada. Professional Paper 42, U. S. Geological Survey. Washington, 1905.

[21]F. L. Ransome.—The geology and ore deposits of Goldfield, Nevada. Professional Paper 66, U. S. Geological Survey. Washington, 1909.

Manhattan and Bullfrog.[22]

Gold and argentiferous galena occur in lodes and veins in Silurian metamorphics near intrusive granites.

Bullfrog.

Native gold and silver occur in nearly vertical mineralized faults and fissures.

Idaho.

The Coeur d'Alene district.[23]

The ore has been precipitated from solutions under great pressure in fissures of a complicated system of faults. It is in the form of galena with siderite gangue in country rocks of highly folded schists and quartzites.

Wood River district.

Ores largely altered by surface oxidation and irregularly distributed in limestones.

New Mexico.[24]

Lake Valley district.

Ores are galena, cerussite, and chloro-bromides in Paleozoic limestones.

The silver districts about Silver City.

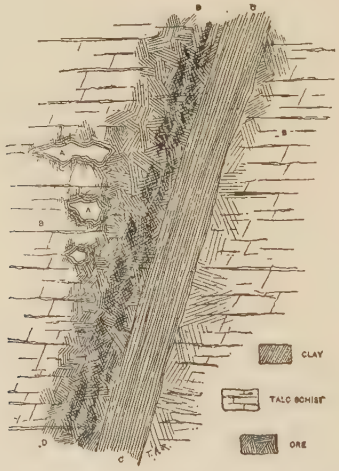

Fig. 59.—Section across a vein in the Hillside mine, Yavapai county, Arizona, showing the ore scattered through the clay. (Rickard.)

[22]F. L. Ransome.—Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada; with notes on the Manhattan district, by G. H. Garrey and W. H. Emmons. Bul. 303, U. S. Geological Survey. Washington, 1907.

[23]F. L. Ransome and F. C. Calkins. The geology and ore deposits of the Coeur d'Alene district, Idaho. Professional Paper 62, U. S. Geological Survey. Washington, 1908.

[24]Lindgren, Graton, and Gordon.—The ore deposits of New Mexico. Professional Paper 68, U. S. Geological Survey. Washington, 1910.

Arizona.

Tombstone region.

Ore is horn silver, associated with galenite, free gold, pyrite, and lead carbonate.

Other silver regions of the United States.

California produces some silver as a by-product of gold.

Washington.[25] At Monte Cristo the ore occurs in veins along a complicated system of joints.

Texas.[26]

Presidio mine has argentiferous galena in pockets and impregnations in limestones.

Dakota (the Black Hills), Michigan, North Carolina, Oregon and Alaska are all silver producers.

Relative importance.[27]

Effect of coinage legislation upon the price and output of silver.

The value of silver.

The gold standard.

Silver sold for $1.37 per ounce in 1857; in 1910 the price was $0.55 per ounce.

[25]J. E. Spurr.—The ore deposits of Monte Cristo, Washington. 22nd ann. rep. U. S. Geological Survey, pt. II, 785-865. Washington, 1901.

[26]H. M. Adkinson.—The silver mines of Texas. Engineering and Mining Journal, LXXIV, 150-151. New York, 1902.

[27]Clarence King.—Production of the precious metals in the United States. Second ann. rep. U. S. Geological Survey, 331-401. Washington, 1882.

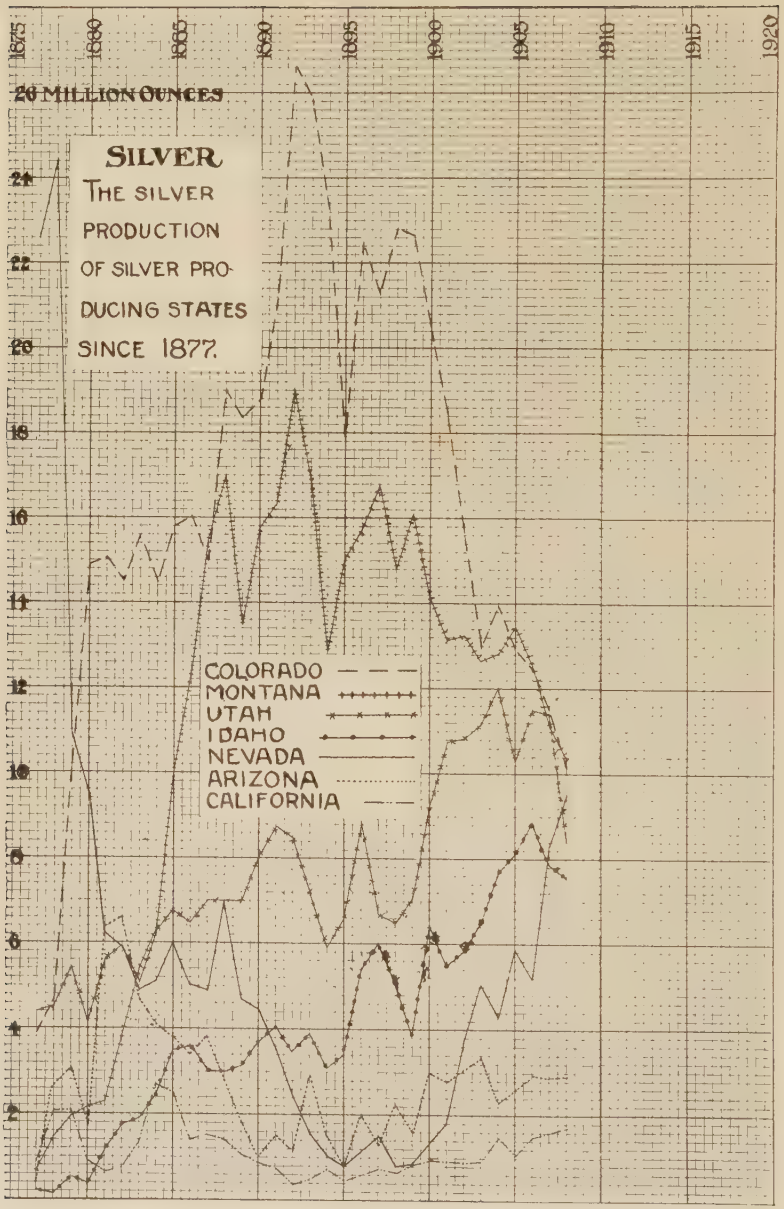
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
20 MILLION OUNCES
SILVER
THE SILVER PRODUCTION OF SILVER PRODUCING STATES SINCE 1877.
24
22
20
18
16
14
12
10
8
6
4
2
COLORADO
MONTANA
UTAH
IDAHO
NEVADA
ARIZONA
CALIFORNIA

Fig. 60.

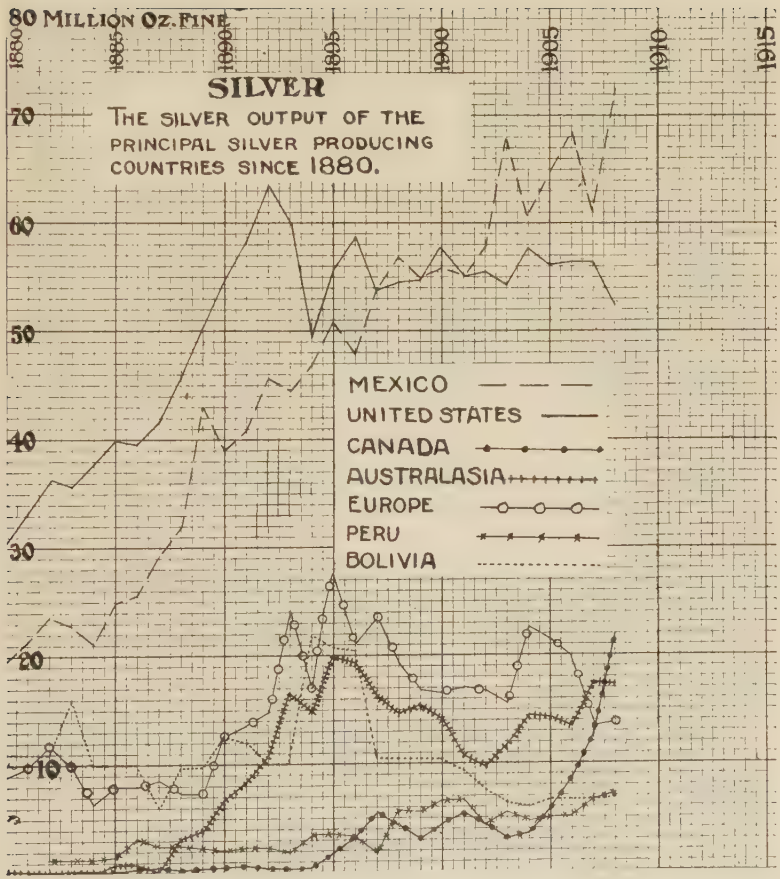
80 MILLION OZ. FINE
SILVER
THE SILVER OUTPUT OF THE PRINCIPAL SILVER PRODUCING COUNTRIES SINCE 1880.
MEXICO
UNITED STATES
CANADA
AUSTRALASIA
EUROPE
PERU
BOLIVIA
70
60
50
40
30
20
10
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 61.

COPPER.

Copper is a soft, highly ductile, red-brown metal having a specific gravity of 8.9. Its most valuable properties are its conductivity, malleability, and its availability in the manufacture of various alloys.

Uses.

For conductors of electricity. Conductivity of silver 100, of copper 96.
In the manufacture of alloys, brass, bronze, etc.[1]
Copper plate engraving, calico printing.

Ores.[2]

Native copper (Cu=100).

Sulphides.

Chalcocite (Co_2S), cuprous sulphide (Cu=79.8, S=20.2).

Chalcopyrite (Cu=34.5, Fe=30.5, S=35.0). Cu FeS_2 or Cu_2S Fe_2S_3, sometimes with silver and gold.

Bornite, crystallized Cu_3FeS_3, (Cu=55.5, Fe=16.4, S=28.1), proportions varying.

Oxides.

Cuprite, cuprous oxide, Cu_2O (Cu=88.8, O=11.2).

Tenorite, cupric oxide, CuO (Cu=79.8, O=20.2).

Carbonates.

Malachite, $Cu_2CO_4 + H_2O$. (Cu=57.4), say carbon dioxide 19.9, cupric oxide 71.9, water 8.2.

Azurite, $Cu_3C_2O_7 + H_2O$. (Cu=55.22), Co_2 25.6, cupric oxide 69.2, water 5.2.

Silicates.

Chrysocolla, Cu $SiO_3 + 2H_2O$. (Cu=36.1 + silica and water), silica 34.3, copper oxide 45.2, water 20.5.

Relative values.

Occurrence and Association.

In veins, in regular bodies and disseminated through the rocks.

[1]Dr. M. Stack.—Bibliographie der metallegierungen. 77. Hamburg u. Leipzig, 1903.
T. K. Rose.—Progress in metallurgy; alloys of Al_2Cu. Nature. LXIII, 232-233. London and New York, 1901.

[2]E. Walker.—The copper sulphate deposits at Copaguire, Chile. Engineering and Mining Journal, LXXXV, 710. New York, 1903.

Many minerals are associated with copper.
Gold in California; silver in Montana; tin in Cornwall.
Methods of formation of copper deposits.[3]

Distribution.

Geologic distribution.
It occurs in rocks of all ages.
Keweenawan age of the Lake Superior copper-bearing rocks;
Ages of other deposits.
Geographical distribution.
Copper in Spain; the Rio Tinto mines.[4]

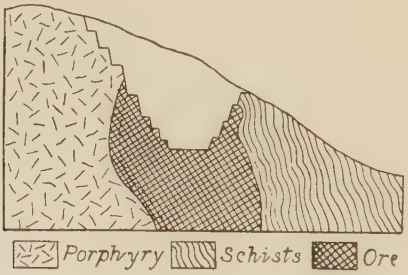

Fig. 62.—Cross-section of the south vein of the Rio Tinto copper mine in Spain. (De Launay.)

Austria.
Prussia.
The Mansfeld mines; 14,250 tons in 1891; 18,557 tons in 1896.
Great Britain.
The Cornwall mines.
Russia.
The Ural district.

[3]J. F. Kemp.—Secondary enrichment in ore deposits of copper. Economic Geology, I, 11-25. 1906.
E. C. Sullivan.—Precipitation of copper by natural silicates. Economic Geology, I, 67-73. 1906.
A. C. Lane.—The theory of copper deposition. Ann. rep. Geological Survey of Michigan for 1903, 239-249. Lansing, 1905.
H. C. Biddle.—Journal of Geology, IX, 430-436. Chicago, 1901.
R. Pumpelly.—The paragenesis of copper, and its associates in the Superior region. Amer. Journal of Science, CII, 188-258; 347-355. New Haven, 1871.

[4]D. Antonio, L. Anciola y D. Eloyde Cassio.—Mémoria sobre las minas de Rio Tinto. Madrid, 1856.
L. de Launay.—Mémoire sur l'industrie du cuivre dans la région d'Huelva. Ann. des Mines, 8me Sér. XVI, 427-516. Paris, 1889. (Bibliography.)

Japan,[5] Mexico,[6] Cuba.[7]

Enrichment in post-Cretaceous diorite strikes.

Queensland.[8]

Copper oxide in pre-Cambrian slates, schists, and metamorphosed sediments at contacts with intrusive granites and diorites.

New South Wales.[9]

Chile.[10]

At one place an extinct volcanic crater, three miles in circumference, and filled with tuff, is surrounded by highly fractured diorite which is mineralized as far as three miles out from the crater.

Bolivia.

New discoveries and little development.

Africa.[11]

Deposits of silicates and oxides forming 7 per cent of the rock.

The Principal Copper Regions of North America.[12]

North America produces two-thirds of the world's supply of copper. Most of the copper produced in America comes from six regions: (1) the Arizona region; (2) the Butte City region of Montana; (3) the Lake Superior region of Michigan; (4) the Utah region; (5) the Nevada region;[6] the California region.

I. The Lake Superior Region, Michigan.[13]

French explorers in the seventeenth century discovered the deposit.

[5]R. J. Frecheville.—Description of the Besshi copper mine in Japan. Trans. Royal Geological Society of Cornwall, X, 113-119. Penzance, 1882.

[6]J. F. Kemp.—The copper-deposits at San Jose, Tamaulipas, Mexico. Trans. Amer. Inst. Min. Eng., XXXVI, 178-203. New York, 1906.

[7]T. W. Vaughan.—The copper mines of Santa Clara province, Cuba. Engineering and Mining Journal, LXXII, 814-816. New York, 1901.

[8]G. W. Williams.—The Cloncurry copper district, Queensland. Engineering and Mining Journal, LXXXVIII, 155-159. New York, 1909.

B. Dunstan.—Moonmera, Queensland, its minerals and copper mines. Geological Survey of Queensland. Publication 195. Brisbane, 1904.

[9]J. E. Carne.—The copper-mining industry.....in New South Wales. Sydney. 2nd ed. 1908.

[10]Wm. Braden.—The Braden copper mines in Chile. Engineering and Mining Journal, LXXXIV, 1059-1062. New York, 1907.

[11]H. Battgenbach.—Les gisements de cuivre du Katanga. Trans. Soc. Géol de Belgique. Liége, 1905.

[12]W. H. Weed.—The Copper Production of the United States. Bulletin 260, 211-250. U. S. Geological Survey. Washington, 1905.

[13]J. W. Foster and J. D. Whitney.—Report on the geology and topography of Lake Superior land district, in the state of Michigan. Part I, copper lands. Washington, 1850.

R. D. Irving.—The copper-bearing rocks of Lake Superior. Monograph V, U. S. Geological Survey. Washington, 1883. (Bibliography.)

For bibliography of the history of mining in the Lake Superior region, see Twenty-third ann. rep. Geological Survey of Minnesota for 1894, 148-155, and Bul. Mus. Comp. Zool., VII, 133-157. Cambridge, 1880.

M. E. Wadsworth.—The origin and mode of occurrence of the Lake Superior copper deposits. Trans. Amer. Inst. Min. Eng., 669-696, XXVII. New York, 1898.

Keweenawan age of the ore-bearing rocks.

The ore is native copper ramifying the rocks, which are sandstones, conglomerates, and diabase.

Character of the ore deposits.

Veins.

Bedding planes.

Impregnations.

The copper-bearing conglomerate and amygdaloids.

Depth of the mines, 4,700 feet+.[14]

The copper belt is narrow and 100 miles long.

II. The Butte Region of Montana.[15]

Age and character of the rocks.

The hill at Butte is granite with rhyolite dikes, and much faulted.

There are three systems of veins and three systems of faults.

The Butte ores are copper sulphide and silver.

The upper 400 feet leached of copper; the lode was first worked for silver.

Bornite and chalcocite below.

The deposits are in fissure veins.

Montana is the only large copper producing district in which the ore is entirely in veins.

III. The Arizona Copper Region.[16]

Three copper-producing districts in southeastern Arizona.

1. The Globe district.[17]
2. The Clifton district.[18]
3. The Bisbee district.[19]
4. The Black Range district.

[14]American Journal of Science, CL, 503. New Haven, 1895.

T. A. Rickard.—Copper mines of Lake Superior. Engineering and Mining Journal, LXXVIII, 585-587; 625-627. New York, 1904.

[15]Weed, Emmons and Tower.—Butte Special folio, Montana, Folio 38, U. S. Geol. Survey. Washington, 1897.

[16]Arthur F. Wendt.—The copper ores of the southwest.—Trans. Amer. Inst. Min. Eng., XV. 25-77. New York, 1887.

James Douglas.—The Copper Queen mine, Arizona. Trans. Amer. Inst. Min. Eng., XXIX, 511-546. New York, 1900.

J. F. Blandy.—The mines of Yavapai county, Arizona. Eng. and Mining Journal, LXIII, 632-634. New York, 1897.

[17]F. L. Ransome.—The geology of the Globe copper district, Arizona. Professional Paper 12, U. S. Geological Survey. Washington, 1903.

[18]W. Lindgren.—The copper deposits of the Clifton-Morenci district, Arizona. Professional Paper 43, U. S. Geological Survey, Washington, 1905.

[19]F. L. Ransome.—The copper deposits of Bisbee, Arizona. Engineering and Mining Journal, LXXV, 444-445. New York, 1903.

Geology and ore deposits of the Bisbee quadrangle, Arizona. Professional Paper 21, U. S. Geological Survey. Washington, 1904.

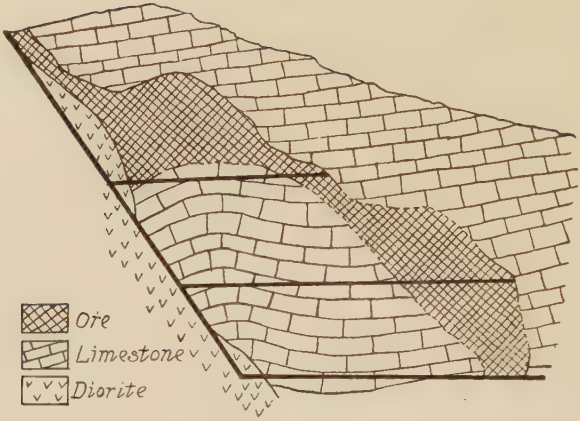

Fig. 63.—Section of the Globe copper mine, Maricopa county, Arizona. The limestone is of Carboniferous age. (Wendt.)

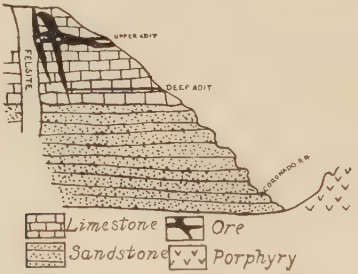

Fig. 64.—Section across Longfellow Hill and Chase creek canyon, Longfellow copper mine, Clifton district, Arizona. (Wendt.)

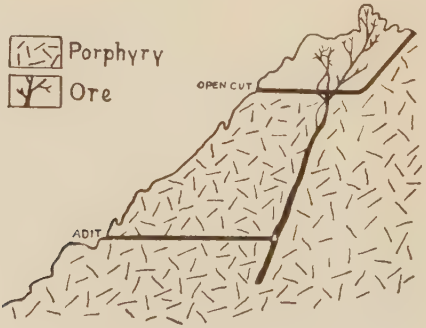

Fig. 65.—Section of Metcalf Hill, Clifton copper basin, Arizona. (Wendt.)

Other Copper districts of the United States.

1. New Mexico.[20]
   Santa Rita mining district.
2. California.[21]
   Copperopolis; Iron Mountain mines at Keswick.[22]
3. Utah.
   Bingham district.[23]
   Silver reef.
   Sulphides of copper impregnate igneous intrusions in Carboniferous limestones.
4. Colorado.[24]
   In Gilpin county copper occurs with gold in veins in granite rocks.
5. Wyoming.[25]
   Sedimentaries metamorphosed by igneous intrusions and impregnated with sulphides along contacts.
6. Idaho.[26]
   Ore is at the contact of limestone with intrusive porphyries.
7. Missouri.[27]
   Chalcopyrite with chert in Cambrian magnesian limestones.
8. New Jersey.[28]
   Minerals deposited in sandstone near intrusive triassic diabase which contains copper sulphides.

[20]Lindgren, Graton, and Gordon.—The ore deposits of New Mexico. Professional Paper 68, U. S. Geological Survey. Washington, 1910.

[21]J. S. Diller.—The copper deposits of the Redding region, California. Bulletin 213, 123-132 and Bulletin 225, 169-179. U. S. Geological Survey. Washington, 1903.

Herbert Lang.—Copper resources of California. Engineering and Mining Journal, LXVII, 442, 470. New York, 1899.

H. Lang.—The copper belt of California. Engineering and Mining Journal, LXXXIV, 909; 963; 1006. New York, 1907.

[22]J. A. Reid.—The ore deposits of Copperopolis, California. Economic Geology, II, 380-417. 1907.

J. S. Diller.—The copper region of northern California. Engineering and Mining Journal, LXXIII, 857-858. New York, 1902.

[23]J. M. Boutwell.—Genesis of the ore deposits of Bingham, Utah. Trans. Amer. Inst. Min. Eng., XXXVI, 541-580. New York, 1906.

J. M. Boutwell.—The Bingham Mining district, Utah. Professional Paper 38. U. S. Geological Survey. Washington, 1905.

Colorado. Bulletin 340, 157-174. U. S. Geological Survey. Washington, 1908.

[24]W. Lindgren.—Notes on copper deposits in Chaffee, Fremont, and Jefferson counties,

[25]A. C. Spencer.—The copper deposits of the Encampment district, Wyoming. Professional Paper 25, U. S. Geological Survey. Washington, 1904.

[26]Ransome and Calkins.—The Coeur d'Alene district, Idaho. Professional Paper 62, U. S. Geological Survey. Washington, 1908.

Wm. Beals, Jr.—The Seven Devils mining district, Idaho. Engineering and Mining Journal, LXIX, 345-346. New York, 1900.

[27]H. F. Bain and E. O. Ulrich.—The copper deposits of Missouri. Bul. 267, U. S. Geological Survey. Washington, 1905.

[28]J. Volney Lewis.—Copper deposits of the New Jersey Triassic. Economic Geology, II, 242-257. 1907.

9. Tennessee.[29]
   Ore is secondary enrichment in old pre-Cambrian metamorphics.
10. North Carolina and Virginia.[30]
    Ore is in metamorphosed pre-Cambrian andesites.
11. Vermont.[31]
12. Alaska.[32]

Relative importance of the different regions in the United States.
American copper mines compared with foreign mines.

Effect of metallurgical processes upon cost of production.
Importance of the electrolytic process.

[29]J. F. Kemp.—The deposits of copper ores at Ducktown, Tenn. Trans. Amer. Inst. Min. Eng., XXXI, 244-265. New York, 1902.

[30]W. H. Weed.—Types of copper-deposits in the southern United States. Trans. Amer. Inst. Min. Eng., XXX, 449-504. New York, 1901.

T. L. Watson.—The copper-bearing rocks of the Virgilina copper district, Virginia and North Carolina. Bul. of the Geological Society of America, XIII, 353-376. Rochester, 1902.

W. H. Weed and T. L. Watson.—The Virginia copper deposits. Economic Geology, I, 309-330. March, 1906.

[31]A. Wendt.—The pyrites, deposits of the Alleghanies. School of Mines Quarterly, VII, 154-188, 218-235, 301-323. New York, 1886.

H. A. Wheeler.—Copper deposits of Vermont. School of Mines Quarterly, IV, 219-224. New York, 1883.

[32]F. E. and C. W. Wright.—The Ketchikan and Wrangell Mining districts, Alaska. Bul. 347, U. S. Geological Survey. Washington, 1908.

H. A. Keller.—The Copper river district, Alaska. Engineering and Mining Journal, LXXXVIII, 1273-1278. New York, 1908.

C. W. Wright.—The copper deposits of Kasaan peninsula, Alaska. Economic Geology, III, 410-417. 1908.

A. H. Brooks.—The copper deposits of the White, Tanana and Copper river regions, of Alaska. Engineering and Mining Journal, LXXIV, 13-14. New York, 1902.

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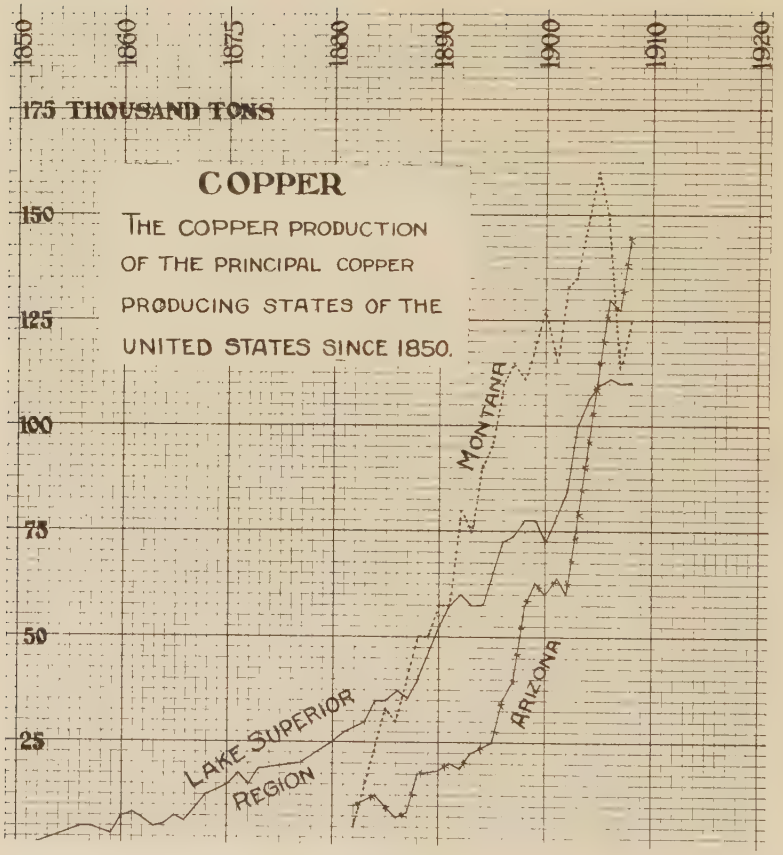
1850
1860
1875
1890
1900
1910
1920
175 THOUSAND TONS
COPPER
THE COPPER PRODUCTION OF THE PRINCIPAL COPPER PRODUCING STATES OF THE UNITED STATES SINCE 1850.
150
125
100
75
50
25
MONTANA
ARIZONA
LAKE SUPERIOR REGION

Fig. 66.

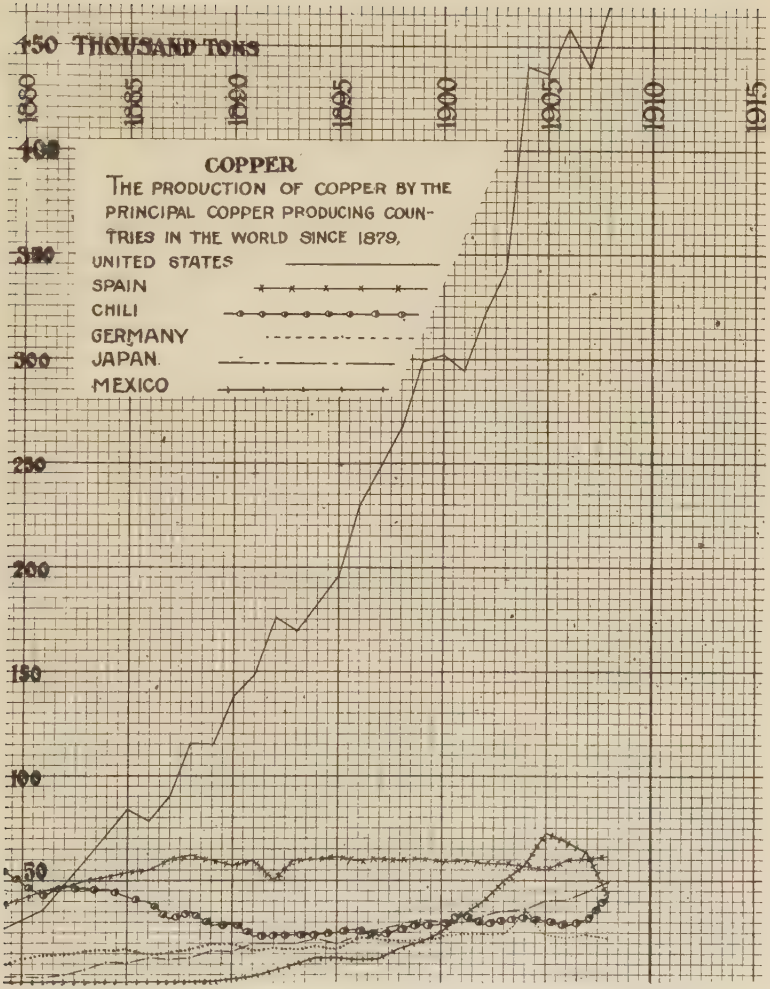
150 THOUSAND TONS
1880
1885
1890
1895
1900
1905
1910
1915
COPPER
THE PRODUCTION OF COPPER BY THE PRINCIPAL COPPER PRODUCING COUNTRIES IN THE WORLD SINCE 1879.
UNITED STATES
SPAIN
CHILI
GERMANY
JAPAN
MEXICO
250
200
150
100
50

Fig. 67.

ZINC.[1]

Zinc is a soft, brittle silver white metal having a specific gravity of 7.2. It does not easily corrode or rust.

Uses.

As an alloy with copper.
Brass is 66 to 73 per cent copper and 27 to 34 per cent zinc.
White metal.
Imitation gold foil.
Zinc white (ZnO) is much used for paint.
Galvanizing nails, iron pipe, sheet iron for roofing.
Electric batteries.
The importance of zinc as compared with iron, copper, and other metals.

Ores.

Spahlerite (Zn 67, S 33), commonly called blende, jack, black-jack, rosin jack.
Smithsonite (ZnO 64.8, $CO_2$35.2), 51.4 metallic zinc.
Calamite (Zn 54.2, SiO_2 25 + water).
Zincite (Zn 80.3, O 19.7).
Franklinite (ZnO, varies from 16 to 23 +).
Willemite (Zn 58.5, SiO_3 27.1).
Comparative importance of the ores.

Occurrence and Association.

Zinc usually occurs in nature associated with lead, and often with copper and silver.
The origin of beds and veins.[3]

Distribution.

Although zinc has a very wide distribution, the zinc of the commerce of the world comes from comparatively few regions.

Geological distribution.

Zinc has a very general geologic distribution, but by far the greater part of the zinc mined comes from Silurian and Lower Carboniferous limestones and cherts.

[1]W. R. Ingalls.—The production and properties of zinc. New York, 1902.

[3]A. M. Finlayson.—Problems of ore deposition in the lead and zinc veins of Great Britain. Quarterly Journal of the Geological Society, LXVI, 299-328. London, 1910.

Arthur Winslow.—The lead and zinc deposits of Missouri. Jefferson City, 1894. (Bibliography.)

Chas. R. Keyes.—Ozark lead and zinc deposits: their genesis, localization, and migration. Trans. Amer. Inst. Min. Eng., XL, 184-231. New York, 1910.

Geographical distribution.

Zinc producing regions in the order of their importance.

1. United States.
2. Belgium.
3. Silesia.
4. Rhine district.
5. France and Spain.
6. Great Britain.

The zinc industry originated in Belgium about 1800.

Zinc in the United States.

There are two principal regions in the United States.

The eastern or Appalachian region.

The western or Mississippi valley region.

The eastern region.

New Jersey, Sussex county.[4]

The ores occur in Lower Silurian and older limestones.

The ores are the red oxides: franklinite, willemite, and zincite.

Pennsylvania, Saucon valley, four miles south of Bethlehem.

Ores from brecciated Chazy magnesian limestone.

The ores are calamine above and sphalerite below.

Virginia.[5]

The ores are calamine and smithsonite in clays derived by decomposition from limestones.

New Hampshire.

Eastern Tennessee.[6]

At Mossy Creek and New Market the ores are sphalerite in brecciated magnesian limestone, and smithsonite nearer the surface.

The Mississippi valley region.

The two principal zinc-producing districts of the Mississippi valley are the Illinois-Wisconsin district and the Missouri-Kansas-Arkansas district.

[4] A. C. Spencer.—The Mine Hill and Sterling Hill zinc deposits, Sussex county, New Jersey. Geological Survey of New Jersey, ann. rep., 25-52. Trenton, 1909.

[5] T. L. Watson.—Lead and zinc deposits of Virginia. Bul. 1, Geological Survey of Virginia. Richmond, 1905.

W. H. Case.—The Bertha zinc mines at Bertha, Virginia. Trans. Amer. Inst. Min. Eng., XXII, 511-536. New York, 1894.

[6] T. L. Watson.—Lead and zinc-deposits of the Virginia-Tennessee region. Trans. Amer. Inst. Min. Eng., XXXVI, 681-737. New York, 1906.

S. W. Osgood.—The East Tennessee zinc mining district. Engineering and Mining Journal, LXXXVII, 401-404. New York, 1909.

The Illinois-Wisconsin district.[7]

The ores have been precipitated from solutions.

Modes of occurrence.

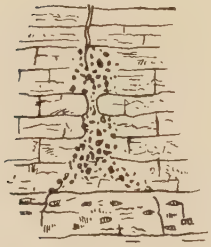

Fig. 68.—Section showing the zinc ore deposit in the Atkinson range in Wisconsin. (Chamberlin.)

Fig. 69.—Section of a mine in the deposit shown in fig. 68 after it is worked out. (Chamberlin.)

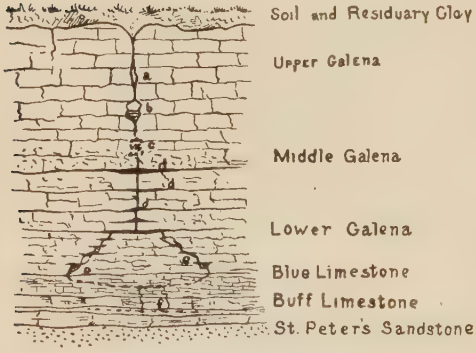

Fig. 70.—Ideal section in the lead and zinc region of Wisconsin, showing the forms of ore deposits at the different horizons. (Chamberlin.)

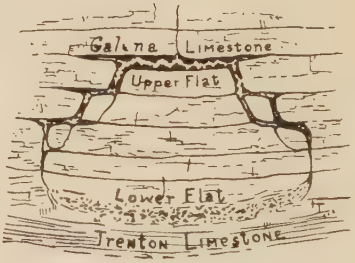

Fig. 71.—Ideal section through "flats and pitches" of the lead and zinc region of Wisconsin. (Chamberlin.)

Relative occurrence of lead and zinc.

Geological horizons.

[7]W. P. Blake.—The mineral deposits of southwest Wisconsin. Trans. Amer. Inst. Min. Eng., XXII, 558-568. New York, 1894.

U. S. Grant.—Structural relations of the Wisconsin zinc and lead deposits. Economic Geology, I, 233-242. 1905.

T. C. Chamberlin.—The ore deposits of southwest Wisconsin. Geol. of Wisconsin, IV, pt. IV, 365-568. Madison, 1879.

The Missouri-Kansas-Arkansas zinc fields.[8]

Ores occur in synclinal troughs and in breccias.

Missouri.

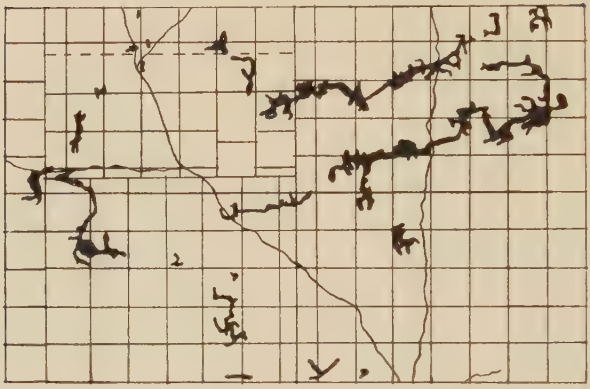

Fig. 72.—Map of a portion of the Eagle lead and zinc mines in Jasper county, Missouri, showing the linear distribution of the ores. Scale: one inch=1,000 feet. (Winslow.)

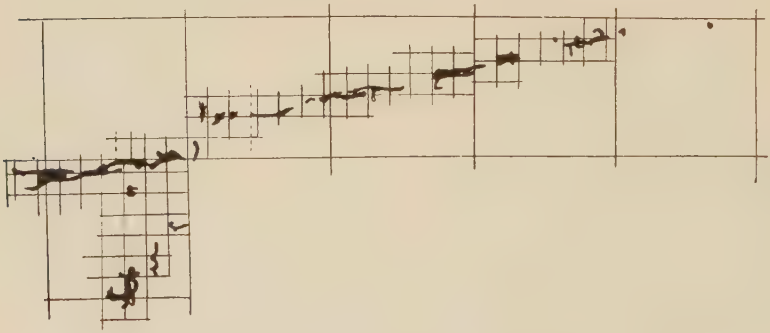

Fig. 73.—General map of the lead and zinc mines north of Aurora, Lawrence county, Missouri, showing the linear arrangement of the ore-bodies. Scale: three inches to one mile. (Winslow.)

[8]F. L. Clerc.—The mining and metallurgy of zinc in the U. S. Min. Resources of the U. S. for 1882, 358-386. Washington, 1883.

Arthur Winslow.—The lead and zinc deposits of Missouri. Geological Survey of Missouri, VI and VII. Jefferson City, 1894. (This work contains a bibliography of lead and zinc.) An abstract of this report is published in the Trans. Amer. Inst. Min. Eng., XXIV, 634-689. New York, 1895.

J. R. Holibaugh.—Lead and zinc mining of southwest Missouri and southeast Kansas. New York, 1895.

Chas. R. Keyes.—Ozark lead and zinc deposits: their genesis, localization, and migration. Trans. Amer. Inst. Min. Eng., XL, 184-231. New York, 1910.

Kansas.[9]
Arkansas.[10]

Nature of the ores.
Geological horizons.
Modes of occurrence: beds, veins, and breccias.

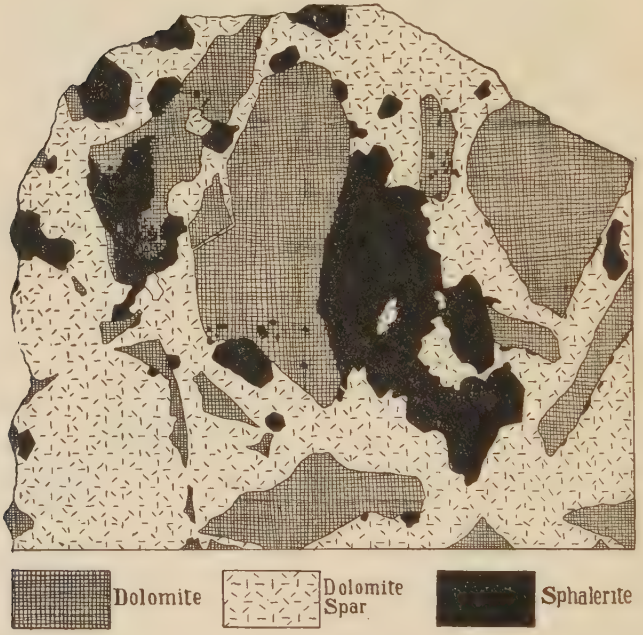

Fig. 74.—Breccia of dolomite cemented with dolomite spar and sphalerite. A type of the zinc ores of north Arkansas and southwestern Missouri.

[9]Haworth, Crane, and Rogers.—Special report on lead and zinc. University of Kansas Geological Survey, VIII. Topeka, 1908.

[10]Adams, Purdue, and Burchard.—Zinc and lead deposits of northern Arkansas. U. S. Geological Survey, Professional Paper 24. Washington, 1904.

J. C. Branner.—The zinc and lead region of north Arkansas. Ann. rep. Geological Survey of Arkansas for 1892, V. Little Rock, 1900.

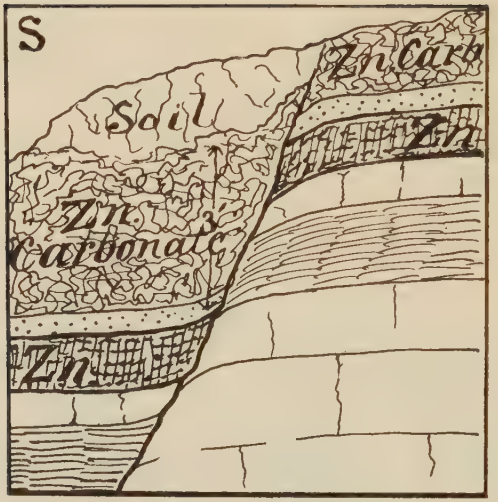

Fig. 75.—A normal fault at the Morning Star zinc mine in north Arkansas, showing a displacement of three feet.

The Iowa zinc deposits.[11]

The New Mexico district.[12]

Ground water level through strata contains oxides of zinc.

Colorado produces much zinc as a by-product from the lead mines.

Zinc found in the silver mines.

Effect of zinc on gold and silver ores.

Probable origin of zinc deposits.[13]

Relative importance of the zinc regions of the United States.

Relative importance of the zinc regions of the world.

[11]A. G. Leonard.—Lead and zinc deposits of Iowa. Iowa Geological Survey, VI, 11-66. Des Moines, 1897.

[12]Philip Argall.—The ore deposits of Magdalena, New Mexico. Engineering and Mining Journal, LXXXVI, 366-370. New York, 1908.

[13]A. G. Leonard.—Origin of the Iowa lead and zinc deposits. American Geologist, XVI, 288-294. Minneapolis, 1895.

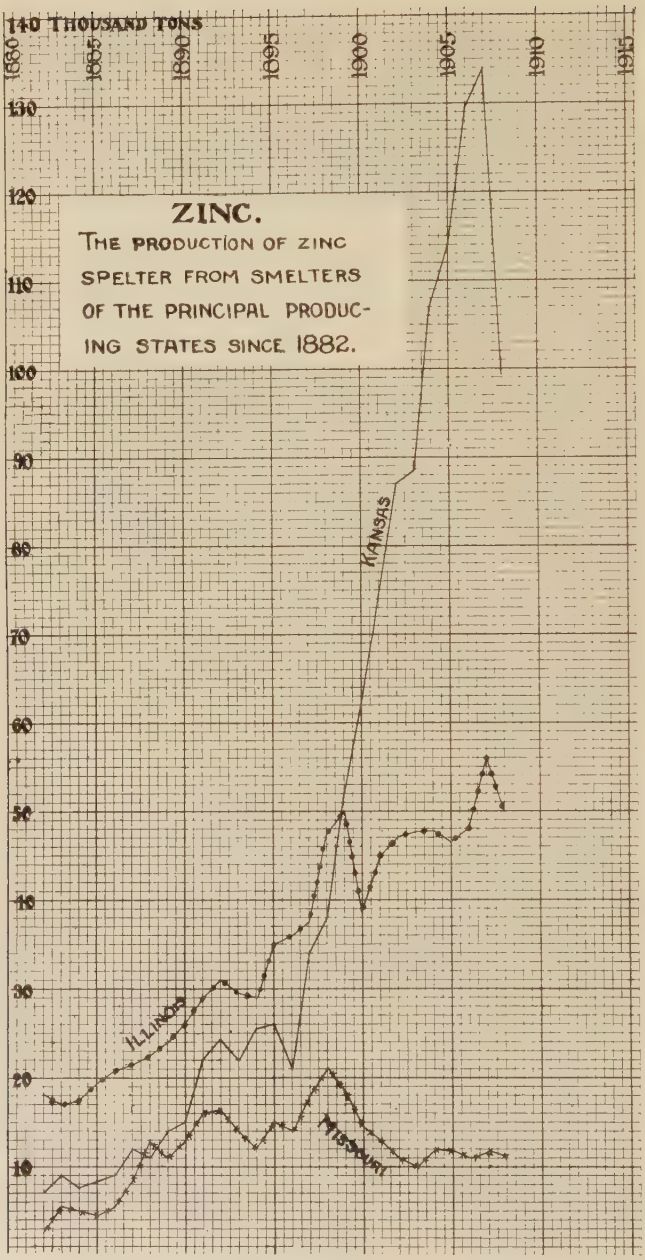
140 THOUSAND TONS
1880
1885
1890
1895
1900
1905
1910
1915
130
120
110
100
90
80
70
60
50
40
30
20
10
ZINC.
THE PRODUCTION OF ZINC SPELTER FROM SMELTERS OF THE PRINCIPAL PRODUCING STATES SINCE 1882.
KANSAS
ILLINOIS
MISSOURI

Fig. 76.

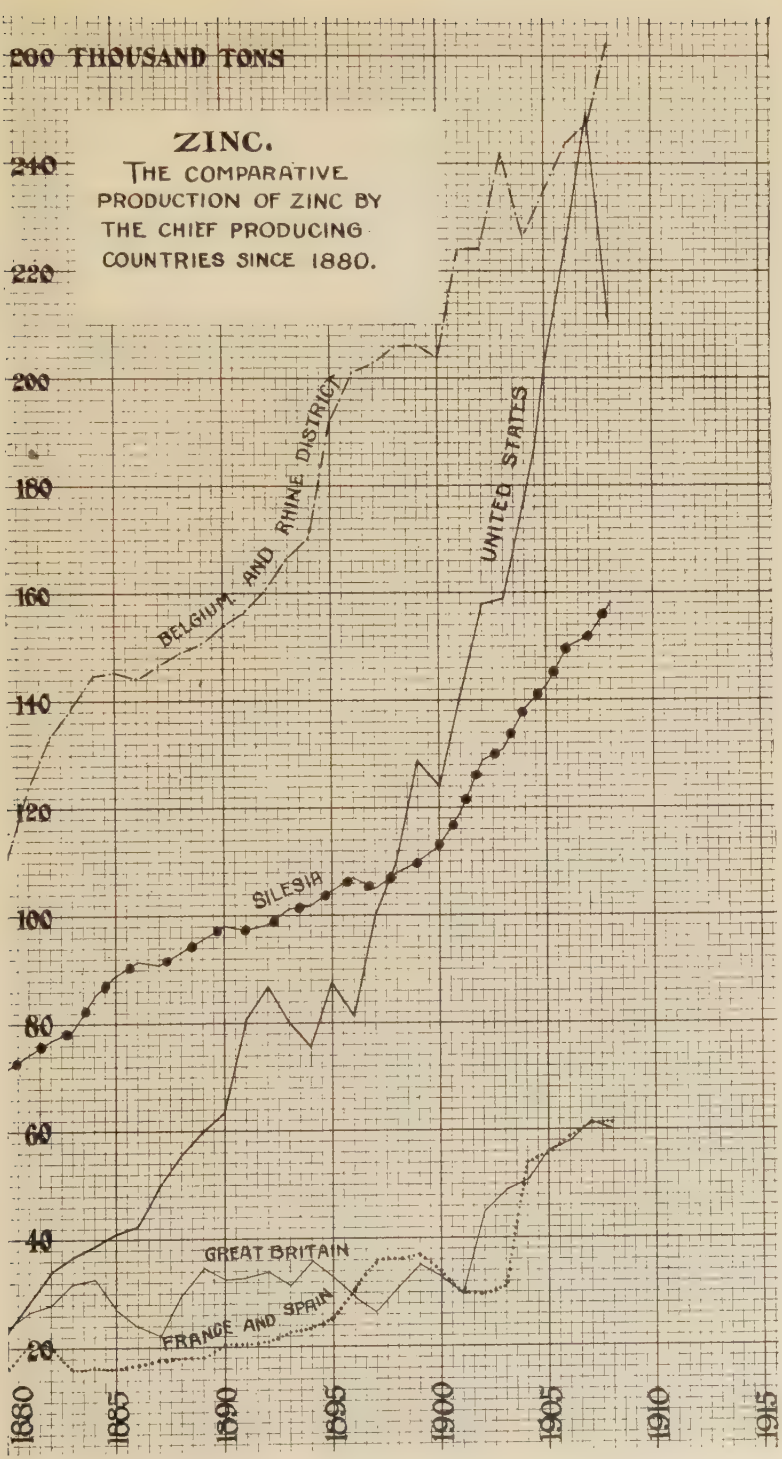
200 THOUSAND TONS
ZINC.
THE COMPARATIVE PRODUCTION OF ZINC BY THE CHIEF PRODUCING COUNTRIES SINCE 1880.
240
220
200
180
160
140
120
100
80
60
40
20
BELGIUM AND RHINE DISTRICT
UNITED STATES
SILESIA
GREAT BRITAIN
FRANCE AND SPAIN
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 77.

LEAD.

Lead is the softest, and, next to gold and platinum, the heaviest metal. The most valuable properties of lead are its softness and ductility, its high specific gravity, and the low temperature at which it melts. (330°C.)

Uses.

Paint: white lead is *lead carbonate,* some is *lead oxide,* and a white *lead sulphate* is now made for paint.[1]

Pigments: certain yellows and red lead.
Chrome yellow, Turner's yellow and orange yellow.

Alloys of lead.
Pewter is tin and from 8 to 18% lead.
Organ-pipe metal is zinc and lead in equal parts.
Solder.
Type metal contains lead, antimony, and bismuth.
Babbitt metal and other anti-friction alloys contains lead and antimony
Shot is 700 parts of lead to 3 parts of arsenic.

Pipes for plumbing; importance of ductility.

Sheet lead for roofing.
Glass making.
Medicine (acetate, carbonate, iodide, etc.).

Ores.

Galena (Pb 86.6, S 13.4).
Argentiferous galena from the silver mines.
Non-argentiferous galena of the Mississippi valley region.

Cerussite (PbO 83.5, CO_2 16.5), known as "dry bone."
Galena and cerussite are usually found together.

Anglesite (PbO 73.6, and SO_3 26.4.)

Lead is usually associated with zinc or silver. The greater part of the lead of commerce is mined as a by-product of silver.

Association and Modes of Occurrence of Lead Ores.[2]

In veins in the Rocky Mountain region.

In the Ozark region they occur in cavities and disseminated through the rocks.

[1] P. C. McIlhiney.—The manufacture of white lead. Mineral Industry during 1900, 435-438. New York, 1901.

[2] Figures illustrating the occurrence of lead ores will be found under the subjects of zinc and silver.
William Wallace.—The laws which regulate the deposition of lead ores. London, 1861.

Distribution of Lead.

Lead has a very wide geologic and geographic distribution.

Most countries yield some lead, but Spain is the most important lead producer.

Geologic distribution.

Lead is confined to rocks of no particular age, but most of it is taken from Paleozoic rocks.

Geographic distribution (principal producers only).[3]

Spain.
United States.
Germany.
Mexico.[4]
Australia (New South Wales).
Great Britain.
Italy.

Lead Regions of the United States.[5]

There are three principal lead regions in the United States: (1) the Appalachian region; (2) the Mississippi region; (3) the Rocky Mountain region.

The Appalachian region.

The ore is in vein is in veins in metamorphic rocks, from Georgia to Maine; the region is not of importance now.

The Mississippi region.[6]

Wisconsin district,[7] principal mines about Mineral Point and Plattville.

The ore occurs as galena with sphalerite in synclinal and other basins where they have been concentrated by underground waters from the country rock.

Iowa district; principal mines about Dubuque.[8]

Galena associated with zinc in Lower Silurian (Galena) limestones in veins, cavities, "flats," and "pitches."

[3]Lead and zinc mining in foreign countries. Special Consular Reports, X. Washington, 1894.

[4]R. A. y Santillan.—Bibliography of Mexican geology and mining. Trans. Amer. Inst. Min. Eng., XXXII, 605-680. New York, 1902.

Lindgren, Graton, and Gordon.—The ore deposits of New Mexico. Professional Paper, 68, U. S. Geological Survey, Washington, 1910.

[5]W. R. Ingalls.—Chronology of lead-mining in the U. S. Trans. Amer. Inst. Min. Eng., XXXVIII, 644-655. New York, 1908.

[6]J. D. Whitney.—The upper Mississippi lead region. Albany, 1862.

[7]U. S. Grant.—Structural relations of the Wisconsin zinc and lead deposits. Economic Geology, I, 233-242. 1906.

Moses Strong.—Geology and topography of the lead region. Geology of Wisconsin, 1873-77, II, pt. IV. Beloit, 1877.

T. C. Chamberlin.—The ore deposits of southwestern Wisconsin. Geology of Wisconsin, 1873-79, IV, pt. IV. Beloit, 1882.

[8]C. A. White.—Report on the geology of Iowa, II, 339. Des Moines, 1870.

Kentucky.[9]

Illinois.

Nature and modes of occurrence of the ore is similar to that of the Wisconsin-Iowa district; in Galena limestone.

Missouri,[10] Kansas, Arkansas, and

Oklahoma.[11]

Galena in veins, cavities, and scattered masses in Paleozoic limestone, from the Cambrian to the Lower Carboniferous, mostly the latter. The ore is often associated with zinc, and originated by the precipitation from underground solutions in faults and breccias and even in beds.

Silicates and carbonates are also found associated with the sulphide ores.

The Rocky Mountain region.

Most of the lead produced at present in the United States comes from the Rocky Mountain region, where it is taken as a by-product of silver from argentiferous galena.

Colorado.

Leadville district.[12]

Lead-silver ores oxidized at the surface, in Carboniferous limestone associated with porphyry.

Sulphide ores at depths.

Aspen.

Lead-silver ores oxidized at the surface, in Carboniferous limestone.

Other Colorado districts.

[9]E. O. Ulrich and W. S. Tangier Smith.—The lead.....deposits of Western Kentucky. Professional Paper 36, U. S. Geological Survey. Washington, 1905.

[10]Adolf Schmidt and Alexander Leonhard.—The lead and zinc regions of southwest Missouri. Geological Survey of Missouri, I, 381-487. Jefferson City, 1874.

Adolf Schmidt.—The lead region of Central Missouri. Geological Survey of Missouri, I, 503-577. Jefferson City, 1874.

J. R. Gage.—Lead mines—southeast Missouri. Geological Survey of Missouri, I, 602-637. Jefferson City, 1874.

Arthur Winslow.—Lead and zinc deposits of Missouri. Trans. Amer. Inst. Min. Eng., XXIV, 634-689. New York, 1895.

Arthur Winslow.—Lead and zinc deposits. Missouri Geological Survey, VI and VII. Jefferson City, 1894.

C. E. Siebenthal.—Structural features of the Joplin district. Economic Geology, I, 119-128. 1906.

F. L. Clerc.—The ore-deposits of the Joplin region, Missouri. Trans. Amer. Inst. Min. Eng., XXXVIII, 320-343. New York, 1908.

[11]C. E. Siebenthal.—Mineral resources of northeastern Oklahoma. Bul. 340, U. S. Geological Survey, 187-230. Washington, 1908.

[12]S. F. Emmons.—Geology and mining industry of Leadville. Monograph XII, U. S. Geological Survey. Washington, 1886.

Max Boehmer.—The genesis of the Leadville ore-deposits. Bul. Amer. Inst. Min. Eng., B 8, 119-122. Feb., 1910.

Montana.
Lead produced from argentiferous galena in silver mining.
Utah.
The silver mines yield much lead as a by-product.
The ore occurs as replacement in Carboniferous limestone.
Idaho.
The Coeur d'Alene district.[13]
Lead-silver ores, in highly faulted and folded quartzites and schists.
They are supposed to have originated by precipitation from hot solutions.
Veins are of large size.
Ore is a filling and silicious replacement along fault cracks.
Galena and siderite are the principal minerals.
New Mexico.
Lead produced from argentiferous galena in silver mining.
Magdalena district.
Non-argentiferous lead ores.
Nevada.
Lead a by-product in silver mining.
Relative importance of the different regions of the United States.
Lead was first smelted in the United States in 1825; in 1872 the silver-lead ores came into the market.

[13]Ransome and Calkins.—The Coeur d'Alene mining district. Professional Paper, U. S. Geological Survey, 62. Washington, 1908.

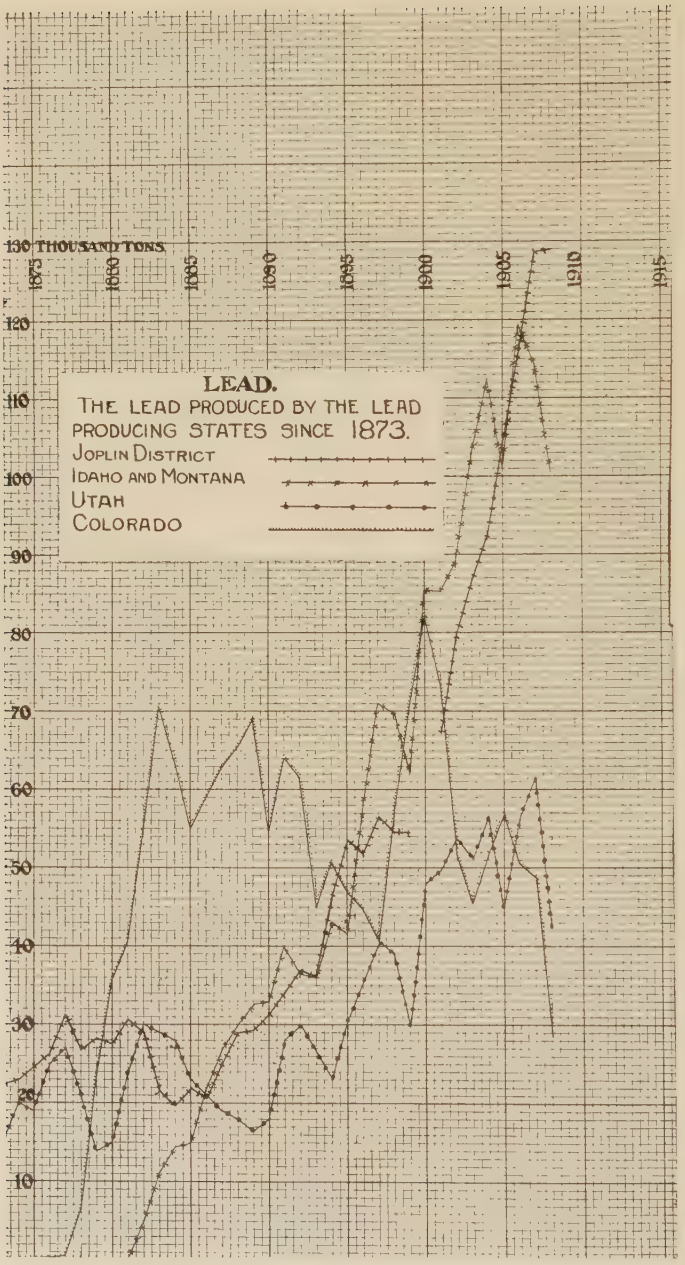
LEAD.
THE LEAD PRODUCED BY THE LEAD PRODUCING STATES SINCE 1873.
JOPLIN DISTRICT
IDAHO AND MONTANA
UTAH
COLORADO
130 THOUSAND TONS
120
110
100
90
80
70
60
50
40
30
20
10
1875
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 78.

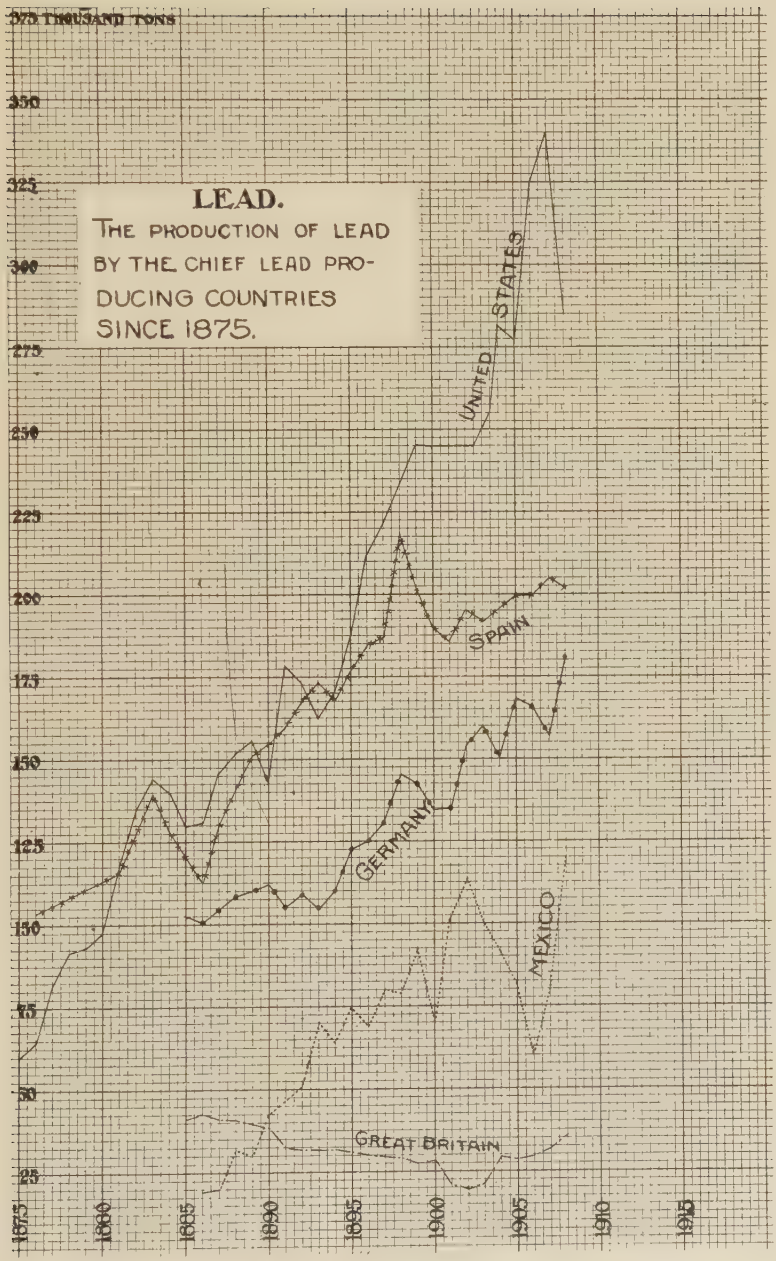
LEAD.
THE PRODUCTION OF LEAD BY THE CHIEF LEAD PRODUCING COUNTRIES SINCE 1875.
375 THOUSAND TONS
350
325
300
275
250
225
200
175
150
125
100
75
50
25
UNITED STATES
SPAIN
GERMANY
MEXICO
GREAT BRITAIN
1875
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 79.

TIN.[1]

Tin is a white metal having a low specific gravity (6.54). It is soft, rather brittle, and does not easily corrode or rust.

Uses.

Manufacture of alloys: pewter, bronze, britannia metal, gun metal, and bell metal.
As tin plate.
Tin foil.
For calico printing in the form of salts with acids.
For tinning water and gas pipes.

Ores.

Tin is mined only as Cassiterite (SnO), tin 78.67, oxygen 21.33.
Stannite (perhaps $Cu_2S.FeS.SnS_2$), tin 27.5, copper 29.5, iron 13.1, sulphur 29.9. It sometimes contains zinc. (Sn 27, Cu 30, Fe 13, S 30.)

Modes of Occurrence and Association.[2]

Tin ores are found in, or associated with, granites, and as placer deposits in the form of stream tin.
The stream deposits are derived from the granites, and are the chief source of supply.

Distribution.

Geological.

Tin occurs as impregnations in pegmatite veins and granites, ranging in age from pre-Cambrian to Tertiary. Placer deposits are usually of Pleistocene age.

Geographical.

The tin deposits of Cornwall[3] and Devonshire, England, have been worked for 2,000 years.

[1]W. de L. Benedict.—Tin. The Mineral Industry, I, 439-462. New York, 1892.

[2]F. L. Hess and L. C. Graton.—The occurrence and distribution of tin. Bul. 260, U. S. Geological Survey, 161-187. Washington, 1905. (Contains bibliography.)

Sydney Fawns.—Tin deposits of the world. 2nd edition. London, 1905. (Contains bibliography.)

Arthur G. Charleton.—Tin: describing the chief methods of mining, dressing and smelting. London, 1884.

[3]E. Skewes.—The Red River tin stream, Cornwall. Engineering and Mining Journal, LXXIV, 178-180. New York, 1902.

[4]J. A. Phillips and Henry Louis.—A treatise on ore deposits. Tin, 28-31, 197-231. London, 1896.

C. Le Neve Foster.—On the great flat lode of Redruth, etc. Quarterly Journal of the Geological Society, XXXIV, 640-659. London, 1878.

The ore occurs as sulphides in slate at the contact with granite.[4]
Copper and zinc are associated with the tin near the surface.

Tin deposits elsewhere in Europe.
Prussia: secondary replacement in granite.
Russia: quartz veins in granite and schist.

The tin of the East Indies.
The Malay Peninsula.[5]
In the Malay Peninsula tin impregnates old granite and quartz veins. Mining is principally in the alluvial and placer gravels. These deposits yield 75% of the world's supply.
Islands of Banca and Biliton off Sumatra.
Cassiterite impregnating granite and concentrated in stream deposits.

Australia: Queensland,[6] Victoria, and New South Wales.[7]
China.
Bolivia: at Potosi tin is a by-product of silver.[8]
Argentina.
Japan.
South Africa.[9] Placer mining of stream tin.
Tasmania.[10]

Tin in America.

Mexico produces small quantities of tin.[11]
In Durango the ore occurs in pockets in trachyte.

[5]P. Doyle.—On some tin deposits of the Malayan Peninsula. Quarterly Journal of the Geological Society, XXXV, 229-232. London, 1879.

J. de Morgan.—Mines d'étain du royaume de Pérak. Annales des Mines, 8me. sér., IX, 408-442. Paris, 1886.

Charles M. Rolker.—The alluvial tin-deposits of Siak, Sumatra. Trans. Amer. Inst. Min. Eng., XX, 50-84. New York, 1892.

J. B. Scrivenor.—The Lahat "pipe": A description of a tin ore deposit in Perak. Quar. Jour. Geological Society, LXV, 382-389. London, 1909.

Frank Owen.—A review of the tin industry of the Malay Peninsula. Mineral Industry, IX, 646-656. New York, 1901.

K. Van Dort.—Tin mining in Siam. Engineering and Mining Journal, LXXXIV, 723-727. New York, 1907.

R. A. F. Penrose, Jr.—The tin deposits of the Malay Peninsula. Journal of Geology, XI, 135-154. Chicago, 1903.

[6]G. W. Williams.—Tin mining and milling in North Queensland. Engineering and Mining Journal, LXXXVII, 1092. New York, 1909.

[7]T. W. E. David.—Geology of the Vegetable Creek tin-mining fields of the New England district, New South Wales. Geological Survey of New South Wales, 4-169. Sydney, 1887.

[8]W. R. Rumbold.—The origin of the Bolivian tin deposits. Economic Geology, IV, 321-364. June, 1909.

[9]W. R. Rumbold.—The South African tin deposits.. Trans. Amer. Inst. Min. Eng., XXXIX, 783-789. New York, 1909.

[10]Geo. A. Walker.—Report on the tin mining district of Ben Lomond, Tasmania. Report of Sec. of Mines, Tasmania, 1900, 302-342. Hobart, 1901.

[11]W. R. Ingalls.—The tin-deposits of Durango, Mexico. Trans. Amer. Inst. Min. Eng., XXV, 146-163. New York, 1896.

Pockets and impregnations of cassiterite in Tertiary rhyolite and along the contacts with Cretaceous limestones and shales.

The United States at present produces no tin. The principal regions where tin is known in this country are the Southern California region, the Black Hills region of South Dakota, and Alaska. Although small quantities of tin are found elsewhere, these are the only localities now known where the deposits promise to be of any value.

Tin of the Black Hills.[12]

Harney's Peak; mode of occurrence.

Tin of Southern California.[13]

Temescal mines.

Mode of occurrence: in granite intrusions in slate and schist.

Replacement of the granite by solution or vapors along fissures.

Tin in North and South Carolina.[14]

Pegmatite dikes carry original cassiterite more or less concentrated at places.

Texas.[15]

Quartz veins carrying tin cut granite which also contains a little tin near the contacts.

Washington.[16]

Black crystalline cassiterite occurs near Spokane as an original constituent in Archean metamorphic rocks and in pegmatite, aplite, and quartz veins.

Alaska.[17]

Stream tin is found on Buck Creek.

At Lost River dikes and granite cut Silurian limestone and carrying cassiterite.

[12]W. P. Blake.—Tin-ore veins in the Black Hills of Dakota. Trans. Amer. Inst. Min. Eng., XIII, 691-696. New York, 1885. Eleventh Census, 1890, 257-265.

[13]H. G. Hanks.—Fourth annual report of the State Mineralogist of California, 115-123. Sacramento, 1884.

H. W. Fairbanks.—The tin deposits at Temescal, Southern California. American Journal of Science, CLIV, 39-42. New Haven, 1897.

[14]F. L. Hess.—Tin deposits of North and South Carolina. Engineering Magazine, 10-20. October, 1906.

[15]W. H. Weed.—The El Paso tin deposits. Bul. 178, U. S. Geological Survey. Washington, 1901.

[16]A. J. Collier.—Tin ore at Spokane, Washington. Bul. 340D, U. S. Geological Survey, 67-77. Washington, 1908.

[17]F. L. Hess.—Tin in.....Alaska. Bul. 260, U. S. Geological Survey, 181. Washington, 1905.

A. J. Collier.—The tin deposits of the York region, Alaska. Bul. 229. U. S. Geological Survey. Washington, 1904. Bibliography.

A. Knopf.—Geology of the Seward Peninsula tin deposits, Alaska. Bul. 358, U. S. Geological Survey. Washington, 1908.

A. H. Fay.—Geology and mining of the tin-deposits of Cape Prince of Wales, Alaska. Trans. Amer. Inst. Min. Eng., XXXVIII, 664-682. New York, 1908. (Bibliography.)

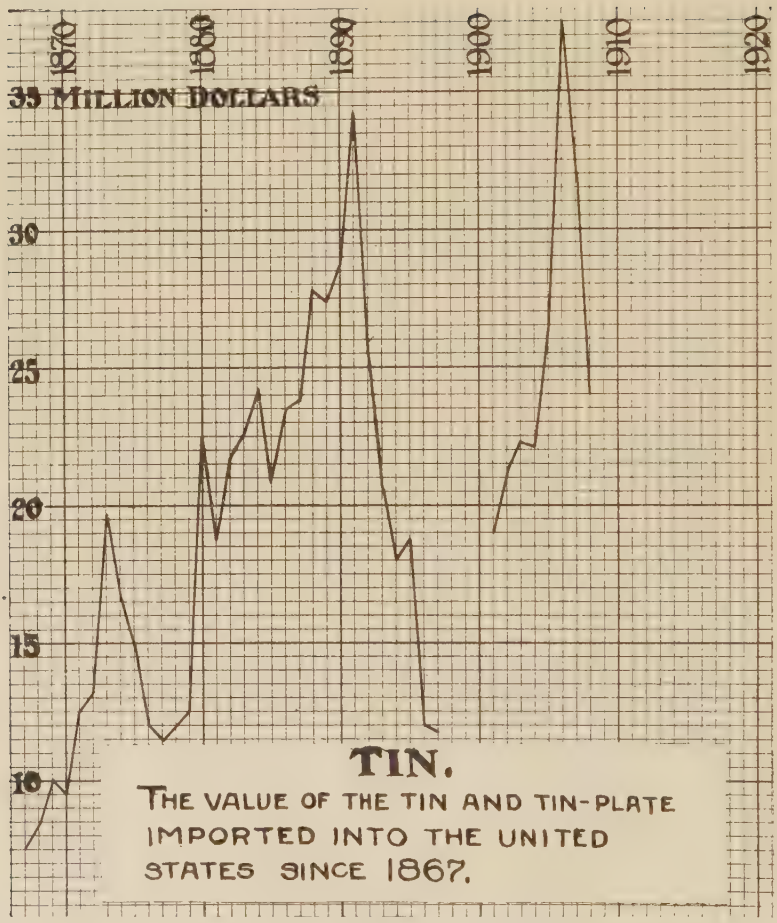
1870
1880
1890
1900
1910
1920
35 MILLION DOLLARS
30
25
20
15
10
TIN.
THE VALUE OF THE TIN AND TIN-PLATE IMPORTED INTO THE UNITED STATES SINCE 1867.

Fig. 80.

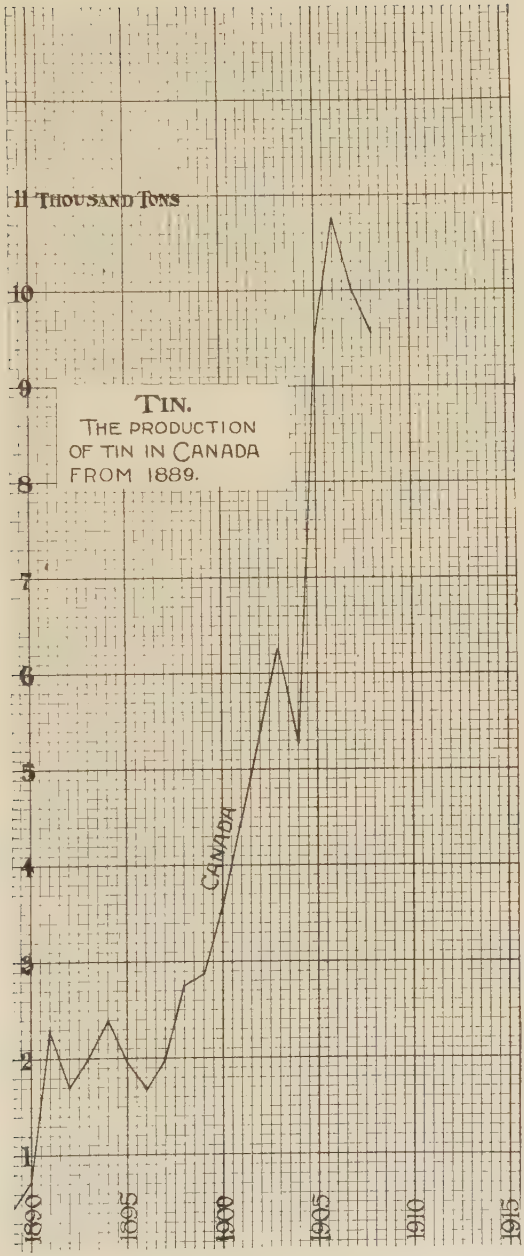
11 THOUSAND TONS
10
9
8
7
6
5
4
3
2
1
TIN.
THE PRODUCTION
OF TIN IN CANADA
FROM 1889.
CANADA
1890
1895
1900
1905
1910
1915

Fig. 81.

MANGANESE.[1]

Manganese is a brittle silver-white metal about as heavy as iron. It is fusible at only the highest temperatures.

Uses.

The chief use of manganese is in the manufacture of steel.
Spiegeleisen has less than 20 per cent of manganese; ferro-manganese has more than 20 per cent of manganese.
For coloring and decolorizing glass and pottery.
In the manufacture of bromine and chlorine.
In making colors for calico printing.
For making dryers used in paint.
As disinfectants.
In the manufacture of oxygen.
Leclanche electric battery.

Ores.

Oxides.

Psilomelane (MnO=77.85, variable).
Pyrolusite, manganese dioxide (MnO_2), Mn=63.2.
Braunite (Mn=69.68), silica 10, manganese protoxide 11.7, manganese sesquioxide 78.3.
Wad, or bog manganese is maganese oxide and from 10 to 25% water.

Carbonates.

Rhodochrosite (manganese protoxide 61.7, CO_2 38.3).

Silicates.

Relative importance of different ores in the production of manganese. The oxides are the most important, psilomelane being the principal mineral. The carbonates are next in importance.

Occurrence and Association.

Manganese is often deposited with and in sedimentary beds; the subsequent decomposition of the rocks leaves the ore as lumps in residual clays.

The great deposits of southern Russia are in horizontal beds between overlying sandstones and underlying limestones.

[1]R. A. F. Penrose, Jr.—Manganese: its uses, ores and deposits. Ann. rep. of the Geological Survey of Arkansas for 1890, I. Little Rock, 1891.

H. Carrington Bolton.—Index to the literature of manganese. Annals of the Lyceum of Natural History, XI, 208-249. New York, 1875.

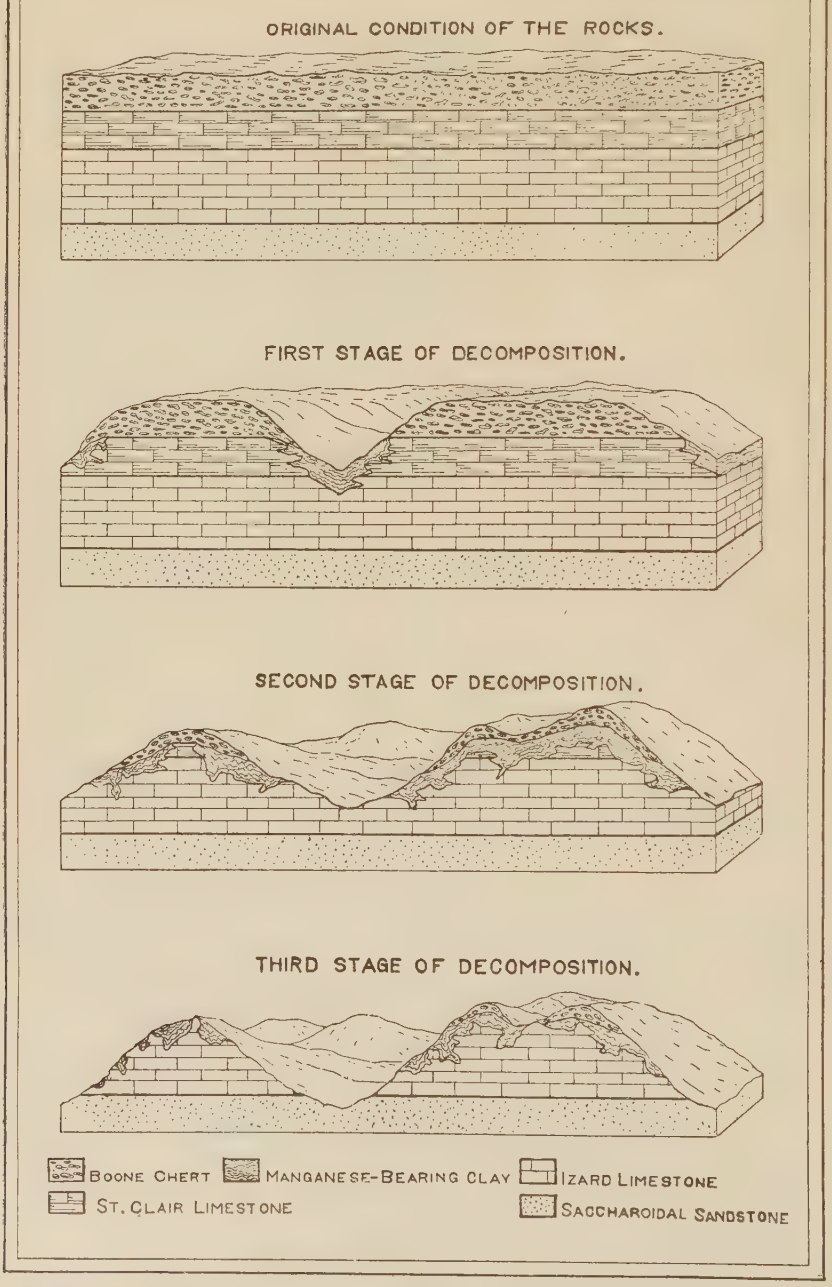

Fig. 82.—Ideal sections showing the formations of manganese-bearing clay from the St. Clair limestone in Arkansas. (Penrose.)

Distribution.

Geological.

Manganese nodules dredged from the deep sea.[2]

Manganese is found in all geologic horizons.

Principal manganese horizons in America are Cambrian, Silurian, and Carboniferous.

Probable source of manganese.[3]

Geographical.

Manganese deposits of the Caucasus.[4]

Furnish 40% of the world's supply.

The manganese deposits of Brazil.[5]

Brazil furnishes 20% of the world's supply.

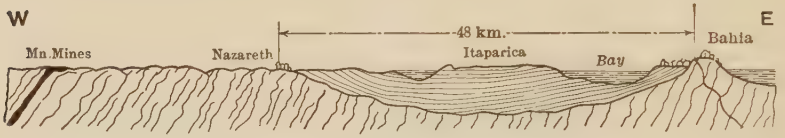

Fig. 83.—Section at and near Bahia, Brazil, showing the structural relations of the manganese deposits at Pedras Pretas.

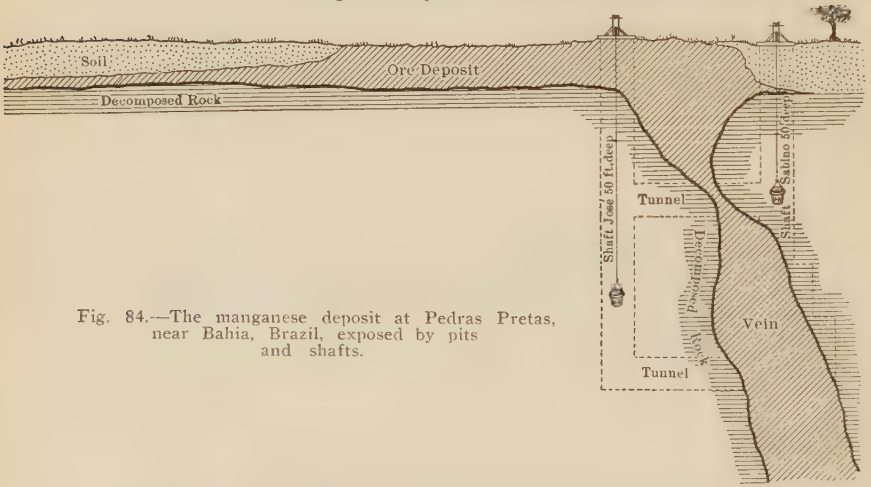

Fig. 84.—The manganese deposit at Pedras Pretas, near Bahia, Brazil, exposed by pits and shafts.

[2]C. Wyville Thomson.—Voyage of the Challenger, II, 15. New York, 1878. Alexander Agassiz, Cruise of the Albatross. Science, New series, X, 833-841. New York, 1899.

[3]W. Mackie.—The conditions under which manganese dioxide has been deposited. Geological Magazine, IX, 558-560. London, 1902.

[4]Frank Drake.—The manganese-ore industry of the Caucasus. Trans. Amer. Inst. Min. Eng., XXVIII, 191-208. New York, 1899.

[5]A. R. Lisbon.—Le manganèse au Brésil. Ann. des Mines. 9me. sér. XV, 115-123. Paris, 1899.

J. C. Branner.—The manganese-deposits of Bahia and Minas, Brazil Trans. Amer. Inst. Min. Eng., XXIX, 756-770. New York, 1900.

H. K. Scott.—The manganese ores of Brazil. Jour. Iron and Steel Inst., LVII, 179-208. London, 1900.

The Panama, Colombia, deposits.[6]

Canada.[7]

Nova Scotia and New Brunswick are small producers.

India.[8]

The mines of Madras make India second in production.

Cuba.[9]

Open cut mines. The ore is in pockets in soft sandstone and is separated by washing.

Manganese of the United States.[10]

The Appalachian region.

Manganese occurs in rocks of several horizons from the Archean to the Tertiary.

Georgia[11] near Cartersville.

Geological horizons and occurrences of the ore.

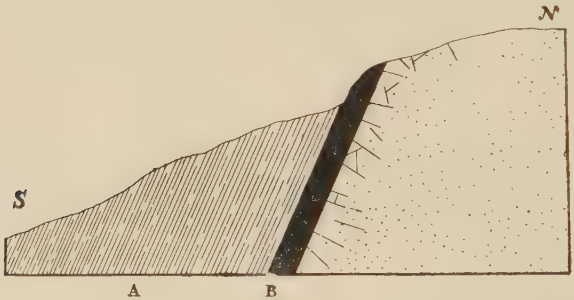

Fig. 85.—Section showing the geology at the Layton manganese mine, Georgia. Manganese and iron are shown by the black band lying between sandstone on the right and manganese-bearing clay on the left. (Penrose.)

[6]E. J. Chibas.—The manganese-deposits of the Department of Panamá, Republic of Colombia. Trans. Amer. Inst. Min. Eng., XXVII, 63-76. New York, 1898.

E. G. Williams.—The manganese industry of the Department of Panama, Republic of Colombia. Trans. Amer. Inst. Min. Eng., XXXIII, 197-234. New York, 1903.

[7]L. W. Bailey.—The mineral resources of the province of New Brunswick. Geological Survey of Canada. Ann. rep. New series, X, 126. Ottawa, 1899.

[8]L. Leigh Fermor.—Manganese-ore deposits of India. Memoirs of the Geological Survey of India, XXXVII, pts. 1-4. Calcutta, 1909.

[9]A. C. Spencer.—The manganese deposits of Santiago province, Cuba. Engineering and Mining Journal, LXXIV, 247. New York, 1902.

A. E. Heighway.—Manganese mining in Cuba. Engineering and Mining Journal, LXXV, 255. New York, 1903.

[10]Edmund Cecil Harder.—Manganese deposits of the United States. Bul. 427. U. S. Geological Survey. Washington, 1910. (Bibliography.)

[11]T. L. Watson.—Geological relations of the manganese-ore deposits of Georgia. Trans. Amer. Inst. Min. Eng., XXXIV, 207-253. New York, 1904.

T. L. Watson.—The manganese ore-deposits of Georgia. Economic Geology, IV, 46-55. Jan.-Feb., 1909.

S. W. McCallie.—A preliminary report on the mineral resources of Georgia. Bul. 23, Geological Survey of Georgia, 126-135. Atlanta, 1910.

Fig. 86.—Section exposed in a pit at the Dobbins mine in Georgia. The black bands represent manganese ore, and the shaded portions clays. (Penrose.)

Virginia.[12]

The ore occurs as nodules in clay in natural basins.

Vermont.

Other localities of the Appalachian region.

The north Arkansas region, near Batesville.[1]

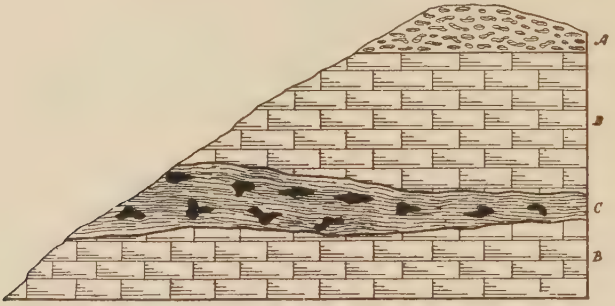

Fig. 87.—Section at the O'Flinn manganese mine in north Arkansas. The manganese is interbedded with the St. Clair limestone. (Penrose.)

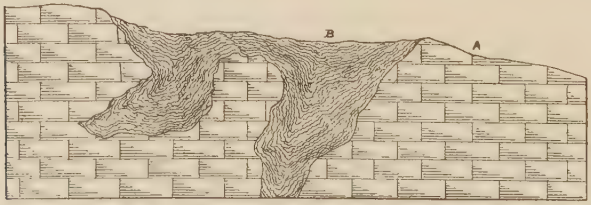

Fig. 88.—Section in the manganese region of North Arkansas, showing the formation of manganese-bearing clay by the decay of the St. Clair limestone. (Penrose.)

[12]E. K. Judd.—The Crimora manganese mine. Engineering and Mining Journal, LXXXIII, 478. New York, 1907.

The ore is found in clays formed by the decomposition of the St. Clair limestone (Silurian).

Texas.

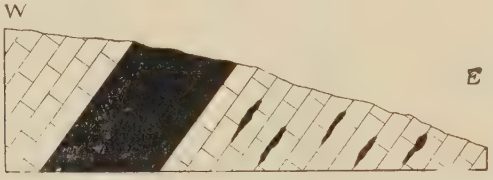

Fig. 89.—Section showing the mode of occurrence of manganese in limestone on the Lewis lands, Cebolla valley, Colorado. (Penrose.)

Colorado.

California.

Occurs in the Franciscan metamorphic series.

Nevada.

The Rocky Mountains.

The Philippines.[13]

Relative importance of the different regions.

1, Russia; 2, India; 3, Brazil.

In 1905 Russia produced 447,000 tons.

In 1905 India produced 284,100 tons.

In 1905 Brazil produced 262,000 tons.

[13]W. D. Smith.—The.....manganese deposits of Ilocos Norte..... Philippine Journal of Science, II, 145-177. Manila, 1907.

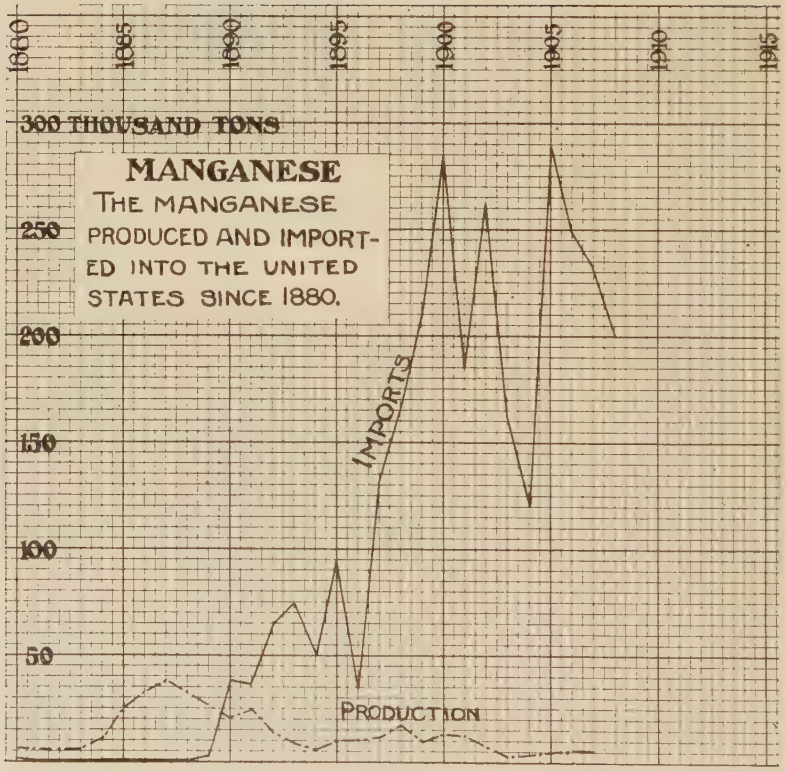
1880
1885
1890
1895
1900
1905
1910
1915
300 THOUSAND TONS
250
200
150
100
50
MANGANESE
THE MANGANESE PRODUCED AND IMPORTED INTO THE UNITED STATES SINCE 1880.
IMPORTS
PRODUCTION

Fig. 90.

COBALT AND NICKEL.[1]

Cobalt resembles iron in appearance, but is harder, more tenacious and ductile, and slightly heavier.

Uses of Cobalt.

As a pigment for blue paints and porcelain; chemical uses, and in the manufacture of cobalt steel.

Most cobalt is a by-product of nickel.

Uses of Nickel.

Nickel plating; manufacture of German silver[2] which is an alloy of nickel, copper, and zinc, and is used for cheap jewelry.

Manufacture of steel.

Effect of nickel on steel.[3]

Armor steel[4] contains 3½% nickel and ¼% carbon.

Coins.

Cobalt and nickel are always associated in nature.

The Ores of Cobalt and Nickel.

Linnaeite (Co 57.9, S 42.1) is a cobalt sulphide with some of the cobalt replaced by nickel.

Nine analyses have the sulphur ranging from 39 to 43, cobalt from 11 to 45, and nickel from 12 to 42.

Millerite (Ni 64.6, S 35.3) is a nickel sulphide.

Niccolite (Ni 43.9, As 56.1) is a nickel arsenide.

Garnierite is a variable hydrous silicate of nickel and magnesia.

Thirteen analyses of garnierite give silica 35.45 to 50.15, nickel oxide 10.20 to 45.15, magnesia oxide 2.47 to 21.70, water 5.27 to 21.65.

Pentlandite (Fe.Ni) S is a sulphide of iron and nickel.

Sulphur 36%, iron 42%, and nickel 22%.

Annabergite (Ni.As) S.

The last two are new minerals found at Sudbury, Ontario.[5]

[1]Mineral Industry, I, 343-358; VI, 495-506. 1892.

[2]Robert A. Hadfield.—Alloys of iron and nickel. The Inst. Civ. Engs. London, 1899.

[3]D. H. Browne.—Nickel-steel: a synopsis of experiment and opinion. Trans. Amer. Inst. Min. Eng., 569-648, XXIX. New York, 1900.

[4]H. F. J. Porter.—Nickel steel as used in commercial work. Engineering and Mining Journal, LXXII, 232. New York, 1901.

[5]W. G. Miller.—Cobalt-nickel arsenides and silver in Ontario. Engineering and Mining Journal, LXXVI, 888-889. New York, 1903.

Occurrence and Association.

The ores of cobalt and nickel occur mostly as segregations in eruptive rocks and in veins. Some cobalt and nickel is obtained as a by-product in lead mining.

Distribution of Cobalt and Nickel.

The most important cobalt-nickel bearing regions of the world are the Sudbury region in Ontario, Canada; New Caledonia, and Norway and Sweden.

The New Caledonia region is about 1,000 miles east of Australia.[6]

Irregular veins and pockets of garnierite in serpentine.

The ore contains 10% nickel.

The ore was discovered in 1867; the mines have been worked since 1874.

Norway.[7]

The ore is a magnetic nickel-iron pyrite, impregnating gabbro, and contains from 1 to 1.2% Ni. The nickel is a replacement of iron.

Sweden.

Great Britain.[8]

Vein of Asbolane (Co. Ni. Mn. Fe, Cu.) SiO. in Carboniferous limestone is formed by the decomposition of a body of cobaltiferous iron ore.

Germany.

Hungary.

Cobalt and Nickel in North America.

The Sudbury (Ontario) region of Canada is the only American region important in the production of cobalt and nickel.[9]

The ore is nickeliferous pyrrhotite and chalcopyrite in fractured zones made by intrusive diorite dikes in Huronian gneiss and igneous rocks. The ore is supposed to have originated through magmatic segregration.

[6]E. Heurteau.—Minerais de nickel (de la Nouvelle-Calédonie). Ann. des Mines, 7me sér. IX, 390-398. Paris, 1876.

Nickel mining in New Caledonia. Engineering and Mining Journal, LXIX, 735. New York, 1900.

[7]Joseph Garland.—On the nickeliferous pyrites of Berg-Nickel mine in the island of Senjen, Norway. Trans. Royal Geological Society of Cornwall, X, pt. V, 161-164. Penzance, 1883.

[8]C. Le Neve Foster.—On the occurrence of cobalt ore in Flintshire. Trans. Royal Geological Society of Cornwall, X, pt. IV, 107-112. Penzance, 1882.

[9]E. D. Peters, Jr.—The Sudbury ore-deposits. Trans. Amer. Inst. Min. Eng., XVIII, 278-289. New York, 1890.

A. M. Charles.—The Sudbury nickel mines in Ontario. Engineering and Mining Journal, LXVII, 144. New York, 1899.

Chas. W. Dickson.—The ore-deposits of Sudbury, Ontario. Trans. Amer. Inst. Min. Eng., XXXIV, 2-67. New York, 1904. (Bibliography.)

A. E. Barlow.—Origin and relations of the nickel and copper deposits of Sudbury, Ontario, Canada. Economic Geology, I, 454-466; 545-563. 1905.

The Cobalt, Ontario, mining district.[10]

The ore is in Huronian gneiss and diabase derived from the diabase. Silver is the principal metal.

Cobalt and nickel regions of the United States.

Cobalt and nickel occurs in several localities in the United States, but they have so far proved of little or no importance.

At the mine La Motte in Missouri some nickel is obtained in smelting the lead.

Pennsylvania.[11]

Cap Mine, Lancaster county, was worked for copper prior to 1852; the mine is now about exhausted.

Virginia.[12]

Nickel occurs with pyrrhotite in gabbro breaking through schists of sedimentary and igneous origin. The ore occurs as secondary replacement of silicates.

[10]T. A. Rickard.—Cobalt, Ontario. Mining and Scientific Press. San Francisco, 1907.

W. G. Miller.—The cobalt-nickel arsenide and silver deposits of Temiskaming. Report of the Bureau of Mines, pt. II, 212. Toronto, 1908.

[11]J. F. Kemp.—The nickel mine at Lancaster Cap, Pa. Trans. Amer. Inst. Min. Eng., XXIV, 620-633. New York, 1895. (Bibliography of the Gap mines.)

[12]T. L. Watson.—The occurrence of nickel in Virginia. Trans. Amer. Inst. Min. Eng., XXXVIII, 683-697. New York, 1908.

CHROMIUM.[1]

Chromium is a gray-white metal which is fusible only at very high temperatures.

Uses.

In manufacturing chrome steel for armor plate, for shoes and dies for stamp mills, and for burglar-proof safes.[2]

Chrome steel contains 2% chromium.

Chrome steel has 60% higher tensile strength than other kinds of steel.

As a pigment in certain greens and yellows.

In the tanning of leather.

Refractory material for furnace linings.[3] For this purpose the ore is crushed, washed, and pressed into bricks.

Ores.

Chromium is not found native, but occurs principally as the chromate of iron, or chromite ($FeCr_2O_4$): chromium sesquioxide 68, iron protoxide 32. It is a greenish black mineral.

Occurrence.

It always occurs in serpentine as irregular masses or pockets.

Probable origin of the chromium segregation found in serpentine.[4]

Chromium is considered as a first cooling product of peridotite, and serpentine a later alteration product.

Distribution.

Canada.[5]

Chromium, imported from Asia Minor[6] which furnishes the bulk of the world's supply.

[1]J. E. Carne.—Notes on chromic iron ore. Mineral resources (of N. S. Wales), I. Sydney, 1898.

[2]F. L. Garrison.—Alloys of iron and chromium. Sixteenth ann. rep. U. S. Geological Survey, pt. III, 610-614. Washington, 1895.

[3]Engineering and Mining Journal, LXIII, 89, 136, 207, 375. New York, 1897.

[3]Wm. Glenn.—Chromite as a hearth-lining for a smelting furnace. Engineering and Mining Journal, LXXII, 637. New York, 1901.

[4]J. H. Pratt.—The occurrence, origin, and chemical composition of chromite. Engineering and Mining Journal, LXVI, 696. New York, 1898.

[5]Phillips Thompson.—Chrome ore in Canada. Engineering and Mining Journal, LXXXVIII, 726. New York, 1909.

Fitz Cirkel.—Report on the chrome iron ore deposits in the eastern townships of Nova Scotia and Quebec. Bul. 29, Mines Branch, Dept. of the Interior of Canada. Ottawa, 1909.

[6]R. W. Lane.—Chrome in Turkey. Engineering and Mining Journal, LXXIV, 275. New York, 1902.

W. F. A. Thomae.—Emery, chrome-ore and other minerals in the Villayet of Aidin, Asia Minor. Trans. Amer. Inst. Min. Eng., XXVIII, 208-225. New York, 1898.

Chromium in the United States.

Very little chromium is produced in the U. S.

Appalachian region[7] in Buncombe county, N. C.

California.[8]

The ore in California occurs in small irregular pockets in serpentine. A few hundred tons are produced annually and used locally.

[7]William Glenn.—Chrome in the southern Appalachian region. Trans. Amer. Inst. Min. Eng., XXV, 481-499. New York, 1896.

J. H. Pratt.—Chromite in North Carolina. Engineering and Mining Journal, LXVII, 261. New York, 1899.

J. H. Pratt.—The chromite deposits of North Carolina. Engineering and Mining Journal, LXX, 190. New York, 1900.

[8]Twelfth rep. California State Mineralogist, 35-38. Sacramento, 1894. Thirteenth rep., 48-50. Sacramento, 1896.

E. C. Harder.—Some chromite deposits in Western and Central California. Bul. 430D, U. S. Geological Survey, 19-35. Washington, 1910.

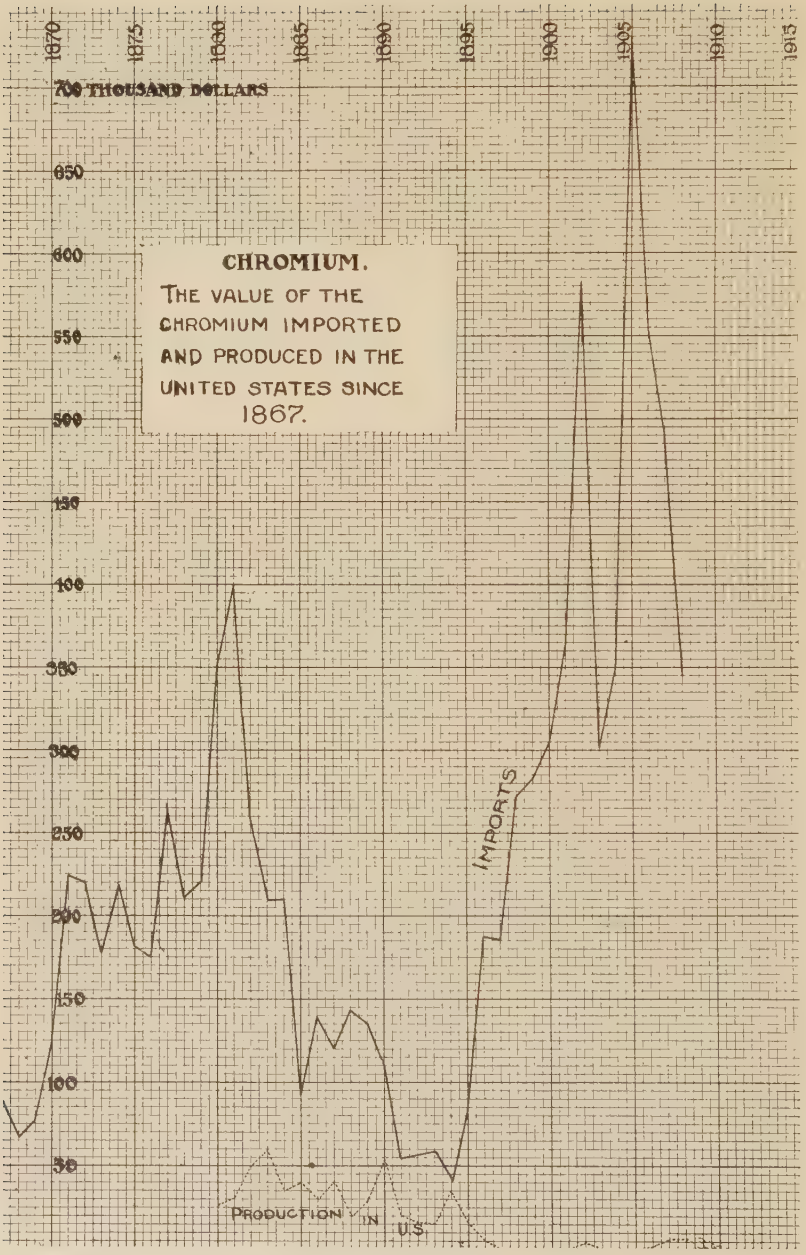
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
700 THOUSAND DOLLARS
650
600
550
500
150
100
350
300
250
200
150
100
50
CHROMIUM.
THE VALUE OF THE CHROMIUM IMPORTED AND PRODUCED IN THE UNITED STATES SINCE 1867.
IMPORTS
PRODUCTION IN U.S.

Fig. 91.

METALS OF THE PLATINUM GROUP.

PLATINUM.[1]

Platinum is a rare metal; it is heavy, silver-white, ductile, and fusible only at a very high temperature (1779° C.)

Uses.

It was used for coinage in Russia from 1828 to 1845.
For the manufacture of chemical, electrical, and surgical apparatus.
Kettles for the manufacture of sulphuric acid.
In mounting diamonds and other costly stones.

Ores.

Native platinum occurs alloyed with other metals of the platinum group. It is often associated with gold.[2]

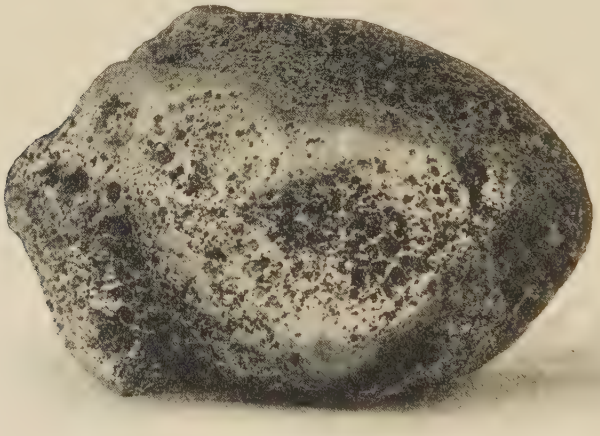

Fig. 92.—The largest platinum nugget ever found in America. Natural size, 3″ x 2¾″; weight, nearly two pounds; from the west coast of South America. (Baker & Co., Newark, N. J.)

Sperrylite ($PtAs_2$); arsenic 43.5, platinum 56.5.

[1] J. L. Howe.—Bibliography of the metals of the platinum group, 1748-1896.
Chas. Bullman.—The mineral industry, I, 373-397. New York, 1893.
J. F. Kemp.—Notes on platinum and its associated minerals. Engineering and Mining Journal, LXXIII, 512-513. New York, 1902.

[2] A. Liversidge.—Crystalline structure of gold and platinum nuggets and gold ingots. Journal and Proceedings of the Royal Society of New South Wales, XXXI, 70-79. Sydney, 1897.

Occurrence and Association.[3]

In Sumatra platinum is associated with wollastonite.

Chromite is the commonest associated mineral.

It is always associated in the original rock with basic olivine peridotite.

It is usually mined from placers, where it is often found associated with gold.

At the Gongo Soco mines of Brazil it was formerly taken with gold from soft schists.

Distribution.

Platinum is mined at but few places in the world. Most of the world's supply comes from the Ural Mountains of Russia.[4]

The placers have been exhausted, and dredging is now the usual method of mining it.

Before 1830 the gravels yielded 2.7 oz. per cubic yard.

In 1830-1838 the gravels yielded ½ oz. per cubic yard.

In 1908 the gravels yielded .09 oz. per cubic yard.

Borneo, Australia, Colombia, and British Columbia all supply small amounts. Brazil formerly furnished a considerable quantity, but has ceased to be a producer.

Discovery reported in New South Wales.[5]

The gold mines of California yield some platinum.[6]

It occurs in the beach sands of the Pacific coast where the sands are derived from serpentines.

Wyoming.[7]

Sperrylite is disseminated through diorite.

The associated minerals are copper, iron, and covellite.

[3]L. Hundeshagen.—Occurrence of platinum. Engineering and Mining Journal, LXXVIII, 344. New York, 1904.

[4]V. X. Pravdinsky.—Russian platinum and foreign companies in Russia. Engineering and Mining Journal, LXXXIX, 1025-1026. New York, 1910.

Daubreé.—On platinum in the Urals. Comptes Rendus de l'Academie des Sciences, LXXX, 707-714. Paris, 1875.

C. W. Purington.—The platinum deposits of the Tura river-system, Ural Mountains, Russia. Trans. Amer. Inst. Min. Eng., XXIX, 3-16. New York, 1900. Engineering and Mining Journal, LXVII, 350-351. New York, 1899.

M. Laurent.—Notes sur l'industrie de l'or et due platine dans l'Oural. Annales des Mines, 8me, sér. XVIII, 537-579. Paris, 1890.

L. Tovey.—Dredging for platinum in the Urals, Russia. Engineering and Mining Journal, LXXXVI, 701-705. New York, 1908.

[5]Engineering and Mining Journal, LXI, 182, 1896; LXII, 126, 220, 1896; LXIII, 333, 1897.

J. B. Jacquet.—The occurrence of platinum in New South Wales. Records of the Geological Survey, V, pt. I, 33-38. Sydney, 1896.

[6]David T. Day.—Notes on the occurrence of platinum in North America. Trans. Amer. Inst. Min. Eng., XXX, 702-708. New York, 1901.

[7]J. F. Kemp.—Platinum in the Rambler mine, Wyoming. Mineral Resources U. S. for 1902, 244-250. Washington, 1904.

Nevada.[8]

Basic dikes penetrate Paleozoic gneisses and carry pyrite, magnetite, chalcopyrite, gold, and platinum.

Statistics.

Price of refined platinum varies from $15 to $38 an ounce; it was $34 in 1910.

Production.

Russia produces nearly all of the world's platinum.

Between 1890 and 1908 the average annual production of that country was 170,000 ounces.

The United States produces from 100 to 1,400 ounces a year.

IRIDIUM.

Iridium is a rare metal, extremely hard, lustrous, and steel-white. It has a very high melting point, and is not attacked by any single acid.

Uses.

In alloys: standard weights and measures.

As a coloring matter in photography, in the ceramic arts, and in jewelry.

In pointing gold pens, fine tools, and in the knife-edges of delicate balances.

Iridium plating.

The price in 1901 was $1.07 per gram.

Occurrence.

Iridium is found as iridosmine (alloy of iridium with osmium) associated with platinum, in Colombia, province of Choco; in the Urals of Russia; in Australia; it is found also in the gold-bearing beach sands of northern California. Iridium also occurs as platiniridium (alloy of platinum and iridium) and in almost all native platinum.

Very little iridium is used, the world's production being but a few tons annually.

OSMIUM.

Osmium is the heaviest and most difficultly fusible metal known.

Uses.

It is used in the form of iridosmine for pointing pens and fine tools.

The price in 1910 was 94 cents per gram.

[8] H. Bancroft.—Platinum in southeastern Nevada. Bul. 430D, U. S. Geological Survey, 44-51. Washington, 1910.

Occurrence.

Osmium occurs alloyed with iridium (iridosmine), and alloyed with platinum. It also occurs in laurite, which is essentially ruthenium sulphide.

PALLADIUM.

Palladium is ductile and malleable; it is a whitish steel-gray metal with metallic lustre.

Uses.

For finely graduated scales.
Compensating balance wheels and hair springs for watches.
Some mathematical and surgical instruments.
The price in 1901 was 94 cents per gram.

Occurrence.

Palladium occurs native and alloyed with gold platinum and iridium.

ALUMINUM.[1]

Aluminum is a tin white metal with a low specific gravity (2.5 to 2.7) and is as hard as silver. It is a good conductor of heat and electricity, and is not readily attacked by acids or moisture.

Uses.[2]

Conductor of electricity.

Manufacture of alloys.

Aluminum-copper alloys.

Aluminum-iron alloys.

Aluminum-magnesium alloys or magnalium.

Manufacture of articles requiring strength and lightness and of articles that should not corrode.

The high price of aluminum prevented its general use until a few years ago.

Sources.

Metallic aluminium or aluminum does not occur in nature; the metal has been known since 1827, but it is only since 1889 that the price of it has been below $2.00 per pound. It was formerly made from cryolite; it is now made from bauxite.[4]

Cryolite (Na_3AlF_6), fluorine 54.4, aluminum 12.8, sodium 32.8, was formerly used in the manufacture of aluminum.

The largest known deposits of cryolite are on the west coast of Greenland, 12 miles from Arksuk, where it occurs in a granite vein in gneiss.[3]

Bauxite ($Al_2O_3.2H_2O$): alumina 73.9, water 26.1.

Aluminum is now made indirectly from bauxite, which is called aluminum ore.[4]

It can be made from kaolin and common clays, but the cost of extraction from these substances is much greater than from bauxite.

[1]J. W. Richards.—Aluminum; its history, properties, etc. Third edition. Philadelphia and London, 1896.

A. E. Hunt, J. W. Langley, and C. M. Hall.—The properties of aluminum, with some information relating to the metal. Trans. Amer. Inst. Min. Eng., XVIII, 528-563. New York, 1890.

J. E. Steinmetz.—Aluminum: considered practically, etc. Jour. Franklin Institute, CL, 272-284. Philadelphia, 1900.

W. C. Phalen.—Aluminum. Mineral Resources U. S. for 1908. Pt. I, 702-708. Washington, 1909. (Bibliography.)

[2]J. W. Richards.—Recent progress in the aluminum industry. Jour. Franklin Inst., CXLIX, 451-459. Philadelphia, 1900.

[3]J. W. Taylor.—On the cryolite of Evigtok, Greenland. Quar. Jour. Geol. Soc. London, XII, 140-144. London, 1856.

W. C. Henderson.—Kryolith, its mining, etc. Jour. Franklin Inst., CXLV, 47-54. Philadelphia, 1898.

[4]James Sutherland.—The preparation of alumina from bauxite. Engineering and Mining Journal, LXII, 320-322. New York, 1896.

J. C. Branner.—The bauxite deposits of Arkansas. Journal of Geology, V, 263-289. Chicago, 1897. (Bibliography.)

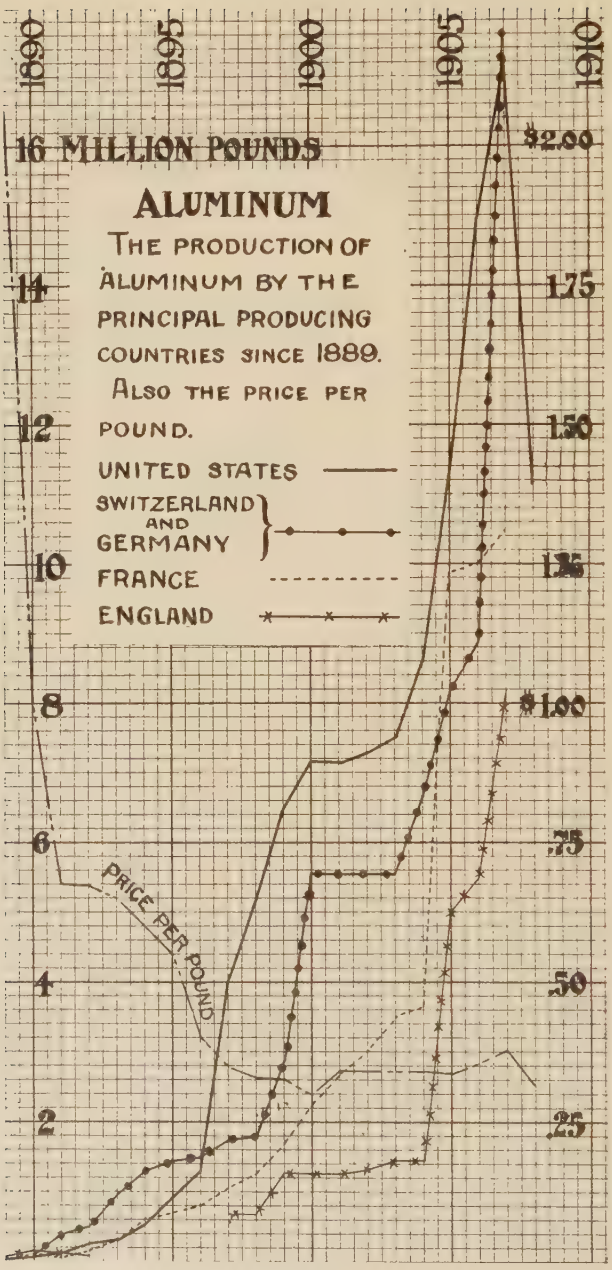
1890
1895
1900
1905
1910
16 MILLION POUNDS
$2.00
ALUMINUM
THE PRODUCTION OF ALUMINUM BY THE PRINCIPAL PRODUCING COUNTRIES SINCE 1889.
ALSO THE PRICE PER POUND.
14
1.75
12
1.50
UNITED STATES
SWITZERLAND AND GERMANY
10
FRANCE
1.25
ENGLAND
8
$1.00
6
.75
PRICE PER POUND
4
.50
2
.25

Fig. 93.

MERCURY (QUICKSILVER).

Quicksilver is a lustrous, tin-white metal which differs from the other metals in being a liquid at ordinary temperatures; it becomes solid at forty degrees below zero. (Faht.)

Uses.

In forming amalgams.

The amalgamation process in extracting gold and silver.

In silvering mirrors.

In medicine in the form of calomel.

In thermometers and mercurial barometers.

As a pigment, especially in China, and formerly by the American Indians.

Ores.

Quicksilver occurs native, usually in liquid globules scattered through the gangue, but sometimes in cavities in quantities large enough to be dipped up.

Cinnabar, mercuric sulphide (HgS), mercury 86.2, sulphur 13.8, is the most important ore; most of the quicksilver of commerce is supplied from it.

Native amalgam of mercury with silver.

There are several other combinations of mercury, but they are of little or no importance as ores.

Modes of Occurrence.

In veins, irregular masses, and impregnations. Confined to no particular kind of country rock. The principal deposits occur in regions of great disturbance, and of former igneous activity, and are newer than the enclosing rock.

All, or nearly all, are contact deposits made by sublimation, or from solutions of dissolved mercury.

In California the deposits are usually associated with serpentine and their distribution is irregular.

Distribution.

Geologic.

Quicksilver deposits are confined to no particular horizon; the deposits of Almaden, Spain, are in Silurian rocks; those of New Almaden, California, are in rocks supposed to be of Jurassic age.

Geographic.

Although quicksilver has a wide distribution, nearly all of the metal of commerce is supplied from Spain (Almaden), California, Austria (Idria), Russia, Mexico, and Italy.

China, Peru, and Asia Minor also produce quicksilver.

Spain.

The Almaden mines[1] of Spain are the most important in the world. The ore is cinnabar, in three parallel, vertical, vein-like beds, approximately parallel to the strike of country rocks of Upper Silurian slates and sandstones. The average thickness of the ore deposits is about 20 feet. The deposits at Almaden are very persistent and of even richness. The mines have been worked since pre-historic times.

Austria.

Idria. Ore: some native metal, but mostly cinnabar, in veins, reticulated masses, and impregnations, in Triassic schists, limestones, and sandstones. The gangue minerals are quartz, calcite, and dolomite. The ore becomes richer as the depth increases.

Italy (Vallalta region).

Ore is cinnabar in impregnations and stringers at the contact of Triassic rocks and quartz porphyry.

Russia.

Cinnabar is found in the gold-mining regions of the Urals, and at other places.

China.

Cinnabar has been produced in great quantities from Kai-Chau.

Peru.

Huancavelica district. The ore is cinnabar in almost vertical Jurassic rocks, and is thought to be sublimed.

Asia Minor.

Ancient mines at Koniah.[2]

Quicksilver is known to occur in many other foreign countries, but they are not producers.

Quicksilver in the United States.[3]

Nearly all the quicksilver produced in the United States comes from Texas and California.

[1]Don Fernando Bernaldez y Don Ramon Figueroa.—Memoria sobre las minas de Almaden y Almadenejos extractada de la escrita por orden de S.M. Madrid, 1861.

[2]F. S. Sharpless.—Mercury mines at Koniah, Asia Minor. Eng. and Mining Jour., LXXXVI, 601-603. Sept. 26, 1908.

[3]H. D. McCaskey.—Quicksilver. Mineral Resources of the United States for 1907, pt. I, 683-692. U. S. Geological Survey. Washington, 1908. (Bibliography.)

Oregon, Utah, Nevada, and Arizona produce small amounts.

California.[4] All of the quicksilver deposits of California are found in the Coast Ranges.

New Almaden, in Santa Clara county, after the Almaden region of Spain, has been the most important quicksilver region of the world.

The ore is cinnabar, with some native metal, in chambered veins, reticulated masses and impregnations in the country rock. The gangue is quartz, calcite, and dolomite.

Two principal fissures unite at a depth enclosing a wedge shaped mass of country rock, which has ore-bearing channels through it.

New Idria, in San Benito county.

The ore is cinnabar, in reticulated masses, impregnations and fissure veins. The country rock is mostly fissured metamorphosed sandstones and shales capped with augite-andesite.

The veins are apparently still filling.

Near Clear Lake and south of it in Lake county there are numerous quicksilver deposits.

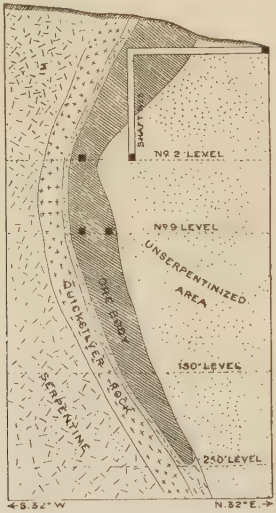

Fig. 94.—Vertical section through shaft no. 3, Great Western quicksilver mine, Lake county, California. (Becker.) Scale, 200 feet to 1 inch.

[4]Geo. F. Becker.—Geology of the quicksilver deposits of the Pacific slope. Monograph XIII, U. S. Geological Survey. Washington, 1888. (Bibliography.)

W. Forstner.—The quicksilver resources of California. Bul. 27, California State Mining Bureau. Sacramento, 1903.

At Sulphur Bank the ore is cinnabar associated with sulphur below the zone of oxidation in shattered rock masses and as impregnations.

At the Great Western mine the ore occurs in "tabulated masses" at the contact between altered sandstone and serpentine.

At the Great Eastern mine in Sonoma county the ore occurs in irregular pipes or chimney deposits in opalized rock.

Texas.[5]

At Terlingua, Brewster county, cinnabar occurs in veins and pockets in Cretaceous limestone and in volcanic rocks. It also impregnates the whole mass to some extent. Calcite is the only associated mineral.

Oregon.[6]

Quicksilver occurs in the Cascade Mountains.

At Steamboat Springs cinnabar occurs as impregnations through decomposed granite in connection with hot springs.

Statistics are usually given in flasks of 76½ pounds.

[5]Benj. F. Hill.—The Terlingua quicksilver deposits. Bul. 4, University of Texas Min. Survey. Austin, 1902.

H. W. Turner.—The Terlingua quicksilver deposits. Economic Geology, I, 265-281. 1905-6. (Bibliography.)

[6]W. B. Dennis.—The quicksilver deposits of Oregon. Engineering and Mining Journal, LXXVI, 539-541. New York, 1903.

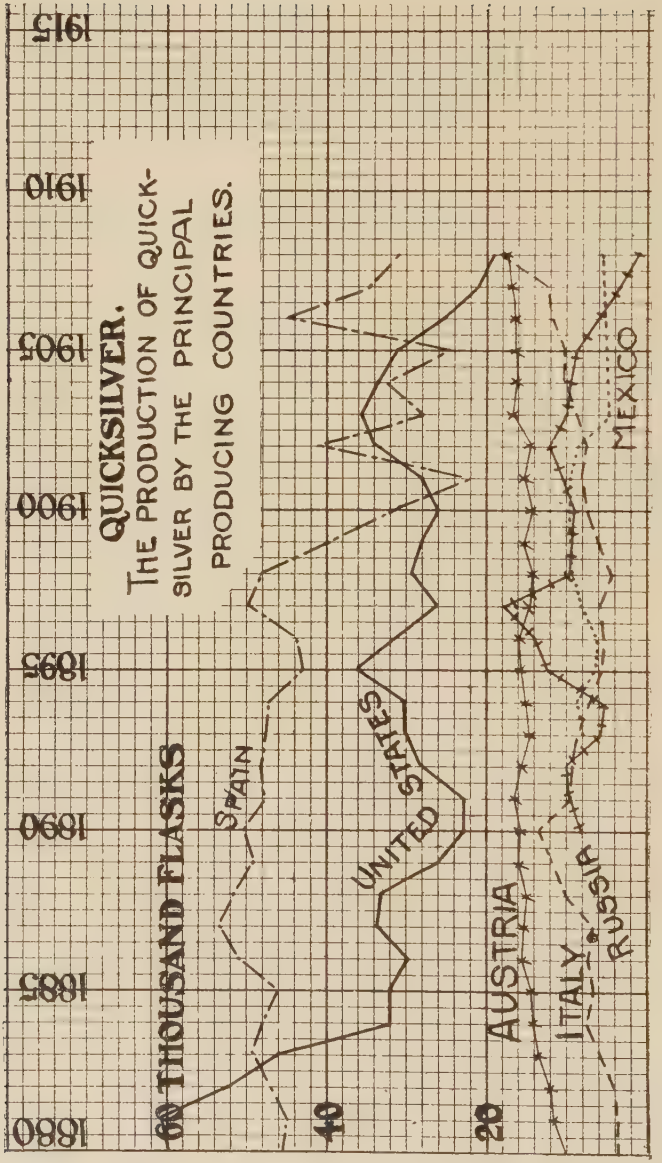
QUICKSILVER.
THE PRODUCTION OF QUICK-SILVER BY THE PRINCIPAL PRODUCING COUNTRIES.
60 THOUSAND FLASKS
40
20
1880
1885
1890
1895
1900
1905
1910
1915
SPAIN
UNITED STATES
AUSTRIA
ITALY
RUSSIA
MEXICO

Fig. 95.

TUNGSTEN.

Tungsten is never found in the native state, and the pure metal is seldom produced artificially. It is a tin white metal having a specific gravity of 19.1 and is harder than quartz.

Uses.

Tungsten added to steel in small proportion (2 to 12 per cent) gives greatly increased hardness and brittleness.[1] This steel is used in making tools.

Filaments of electric incandescent lamps.

In alloys, "magenta bronze," "saffron bronze."

As a pigment in certain yellow and blue paints.

As a mordant for printing cotton cloth and staining paper.

Ores.

Wolframite ($(Fe, Mn)WO_4$): iron protoxide 19.16, manganese protoxide 4.96, tungsten trioxide 75.88, individual analysis.

Scheelite, calcium tungstate ($CaWO_4$): lime 19.4, tungsten trioxide 80.6.

Huebnerite, tungstate of magnesium ($MnWO_4$), containing from 18 to 25 per cent manganese protoxide, and from 73 to 76 per cent tungsten trioxide.

Ferberite, black tungstate of iron, contains about 70 per cent tungsten trioxide.

Occurrence.

Tungsten usually occurs in quartz veins in granite.

Tungsten is found associated with deposits of tin; it occurs at many places, but is produced at few.

Distribution.

Tungsten in Europe: Cornwall, Saxony, Bohemia.

Australasia.

New South Wales.[2]

Queensland.[3]

New Zealand.

[1] F. L. Garrison.—Alloys of iron and tungsten. Sixteenth ann. rep. U. S. Geological Survey, pt. III, 615-623. Washington, 1895.

R. Helmhacker.—Relative resistance of tungsten and molybdenum steel. Engineering and Mining Journal, LXVI, 430. New York, 1898.

[2] J. E. Carne.—Tungsten ores in New South Wales. Mineral Resources (of N. S. Wales), no. 2. Sydney, 1898.

[3] W. E. Cameron.—Wolframite.....mining in Queensland. Report Geological Survey, no. 188. Brisbane, 1904.

United States.[4]

Colorado.[5]

Boulder county produces nearly all the tungsten of the state of Colorado.

It occurs as ferberite in sheeted veins in granite intruded into Paleozoic schists and gneisses. Brecciated zones and cavities are lined with crystals of ferberite which have been deposited from solutions.

South Dakota.[6]

Wolframite impregnates sandy Cambrian dolomites and is associated with cassiterite and scheelite in quartz veins.

Montana.[7]

Huebnerite occurs in shoots and veins formerly worked for silver. It is associated with quartz, copper sulphides, and silver.

California.[8]

At Randsburg[9] in San Bernardino county scheelite occurs in quartz veins in old granites.

It is found at many other places in the desert region of southern California.

Arizona.[10]

Near Dragoon, quartz veins carrying scheelite, wolframite, and huebnerite cut granite. The minerals are probably magmatic segregations.

Nevada.[11]

Scheelite and huebnerite occur at several places in quartz veins cutting granites and schists of Palaeozoic age.

[4]Tungsten.—Mineral Industry, VII, 719-722. Washington, 1899, XVII, 826-835. Washington, 1909.

F. L. Hess.—Tungsten. Mineral Resources of the U. S. for 1908, pt. I, 721-736. U. S. Geological Survey. Washington, 1909. (Bibliography.)

[5]W. E. Greenawalt.—The tungsten deposits of Boulder county, Colorado. Engineering and Mining Journal, LXXXIII, 951-952. New York, 1907.

W. Lindgren.—Some gold and tungsten deposits of Boulder county, Colorado. Economic Geology, II, 453-463. 1907.

[6]F. L. Hess.—Tin tungsten and tantalum deposits of South Dakota. Bul. 380, 131-163. U. S. Geological Survey. Washington, 1909.

J. D. Irving.....Wolframite in the Black Hills of South Dakota. Trans. Am. Inst. Min. Eng., XXXI, 683-695. New York, 1902.

[7]F. Tomek.—Tungsten in Montana. Mining World, XXVIII, 63. Chicago, 1908.

A. N. Winchell.—Notes on tungsten minerals from Montana. Economic Geology, V, 158-165. March, 1910.

[8]Gordon Surr.—Tungsten in California. Los Angeles Mining Review, XXVI, 12-14. April, 1909.

[9]S. H. Dolbear.—Occurrence of tungsten in Rand district, California. Engineering and Mining Journal, XC, 904-905. New York, 1910.

[10]W. P. Blake.—Huebnerite in Arizona. Trans. Amer. Inst. Min. Eng., XXVIII, 543-546. New York, 1899.

[11]F. B. Weeks.—Engineering and Mining Jour., July 6, 1901, p. 8; Bul. 340D, U. S. Geological Survey, 35-42. Washington, 1908.

Connecticut, Idaho, Alaska, Washington, and New Mexico all have deposits of tungsten minerals. The occurrences are similar to those already described.

Statistics.

From 1899 to 1908 the tungsten output in the United States varied from 46 to 1,640 tons.

The United States is now the largest producer; South America, Queensland, and New South Wales are the only other important producing countries.

THE WORLD'S TUNGSTEN OUTPUT.

1905	3,979 tons.
1906	4,320 tons.
1907	6,062 tons.

MOLYBDENUM.[1]

Molybdenum is a white metal with a silvery lustre; it is as malleable as iron; its specific gravity is 9.01.

Uses.

The principal use is in the manufacture of molybdenum steel which is extremely tough.

Tool steel contains from 2 to 4 per cent of molybdenum.

Armor steel contains from 1 to 2 per cent of molybdenum.

It is also used in making disinfectants, pigments, and fire-proof cloth.

Ores.

Molybdenite, the sulphide (MoS_2): molybdenum 60.0, sulphur 40.0, is the principal source of supply; it is lead gray in color, very soft, and resembles graphite.

Wulfenite ($Pb\ MoO_4$): molybdenum trioxide 39.3, lead oxide 60.7.

Modes of Occurrence.

Molybdenum does not occur in the native state. It usually occurs as disseminations or quartz veins in granite or gneiss, and is associated with pegmatite veins from which it is supposed to have originated.

Distribution.

The metal is produced in commercial quantities in but few places. Formerly the chief supply of the world came from Sweden.

Molybdenum in the United States.

Washington[2] in 1902 produced 12 tons of ore. The ore is molybdenite and occurs in a quartz vein in granite. On Railroad Creek, four miles from Lake Chelan, it occurs in a quartz vein four feet thick.

In Maine[1 3] molybdenite occurs disseminated in granite near pegmatite dikes from which the mineral has been derived.

In California[1] molybdenite is desseminated through granite near pegmatite veins at Corona, Riverside county. The mineral is in very fine flakes.

Montana, Utah,[1] Colorado, and Oregon also produce small quantities of ore.

[1]F. L. Hess.—Molybdenum deposits of Maine, Utah, and California. Bul. 340D, U. S. Geological Survey, 3-12. Washington, 1908.

[2]A. R. Crook.—Molybdenite at Crown Point, Washington. Bul. Geological Society America, XV, 283-288. Rochester, 1904.

[3]G. O. Smith.—A molybdenite deposit in eastern Maine. Bul. 260, U. S. Geological Survey, 197-199. Washington, 1905.

Arizona and New Mexico are the chief sources of supply in the United States.

In the United States 9,550 pounds of the metal, valued at about $1.25 per pound, were produced in 1898; 2,000 pounds of ferro-molybdenum (50% molybdenum) were produced the same year. In 1908 the price of 99% metal was $1.50 per pound, and ore containing 95% molybdenum sulphide sold for $450 per ton.

Foreign Countries.

Australia.

Queensland[4] produces the most of the world's supply. In 1906 145 tons, valued at $82,956, were produced.

The molybdenite occurs in granite in irregular quartz veins and masses associated with wolframite and bismuth.

New South Wales[5] in 1906 produced 37 tons of ore valued at $23,366. The molybdenite occurs in quartz veins associated with wolframite and bismuth.

[4]W. E. Cameron.—Wolfram and molybdenite mining in Queensland. Geological Survey Queensland, Rept. No. 188. Brisbane, 1904.

[5]E. F. Pittmann.—The mineral resources of New South Wales, 304-306. Sydney, 1901.

E. C. Andrews.—Molybdenum resources of New South Wales. Bulletin 11 of the Geological Survey of New South Wales. Sydney, 1906.

ANTIMONY.[1]

Metallic antimony has a tin-white color, crystalline structure, and is very brittle; it fuses at a low temperature (430° C.).

Uses.

Medicine.

Pigments: the trioxide makes a white paint, and the sulphide is used to make a red paint.

Alloys.

Alloyed with other metals, antimony gives a hard and brittle product.

Type-metal is an alloy of antimony with lead and bismuth; when less than 15 per cent antimony is used the product expands on cooling.

Babbitt metal is an alloy of tin with antimony and copper (tin 83 per cent, copper and antimony 17 per cent), and is used in lining bearings, bushings, and pillow blocks for shafts of machinery.

Pewter is an alloy of lead and tin with antimony, bismuth or copper.

Britannia metal is an alloy of tin with antimony and other metals, and is used in making tableware which is afterwards plated with silver.

Solder for jewelry is made of antimony and gold.

Antimony and lead are alloyed in varying proportions and used in making storage batteries, linings for coffins, and in the manufacture of toys.

Ores.

Stibnite (Sb_2S_3): antimony 71.4, sulphur 28.6.

Senarmontite (Sb_2O_3): antimony 83.3, oxygen 16.7.

Kermesite (Sb_2S_2O): antimony 75.0, sulphur 20, oxygen 5.

Stibnite is the most important. It is soft, has a metallic steel-gray color, and melts in a candle flame.

Occurrence.

Antimony usually occurs in veins with a quartz gangue.

Distribution.

The principal antimony-producing countries of Europe are those adjacent to the Mediterranean Sea.

France[2] is the most important antimony producer in the world, the annual output of that country being about 5,000 tons. The ore occurs in quartz veins which follow bedding planes in mica-schist.

[1] C. Y. Wang.—Antimony: its history, chemistry, mineralogy, ores, etc. London and Philadelphia, 1909. (Bibliography.)

[2] P. L. Burthe.—Notice sur la mine d'antimoine de Freycenet. Ann. de Mines, 9me sér. IV, 15-33. Paris, 1893.

Portugal, Spain, Austria-Hungary, Italy, Asia Minor, Servia, and Macedonia all produce some.

Borneo and Japan are large producers, annual output being from 3,000 to 4,000 tons.

Other regions are Australia, Nova Scotia, New Brunswick.

In New South Wales[3] stibnite occurs with quartz in lodes and veins cutting Paleozoic sedimentary and metamorphic rocks.

Antimony in the United States.[4]

Antimony is found in many localities in the United States, but little is mined in this country.

Arkansas, Antimony City.[5]

Stibnite is found in the southwestern part of the state in bedded quartz veins in Carboniferous sandstones and shales.

California, in Inyo, San Benito, and Kern counties.

The ore is stibnite in veins with quartz gangue.

Nevada, near Austin, Lander county.

This is one of the most important American localities; the ore occurs as a small vein of almost pure stibnite.

In Humboldt county stibnite occurs in quartz veins.

Utah, Iron county.[6]

Stibnite is desseminated through sandstone and conglomerate following the stratification.

Montana, near Thompson's Falls.

[3]E. F. Pittmann.—The mineral resources of New South Wales. 246-255. Sydney, 1901.

[4]W. P. Blake.—Antimony. Mineral Resources of the U. S. for 1883-84, 641-653. Washington, 1885. The Mineral Industry, II, 13-24. New York, 1894.

[5]T. B. Comstock.—Geology of western central Arkansas. Ann. rep. Geological Survey of Arkansas, I, 136-144. Little Rock, 1888.

F. L. Hess.—The Arkansas antimony deposits. Bul. 340D, U. S. Geological Survey, 13-24. Bul. 340, 241-252. Washington, 1908.

[6]G. B. Richardson.—Antimony in southern Utah. Bul. 340D, U. S. Geological Survey, 25-28. Washington, 1908. Bul. 340, U. S. Geological Survey, 253-256. Washington, 1908.

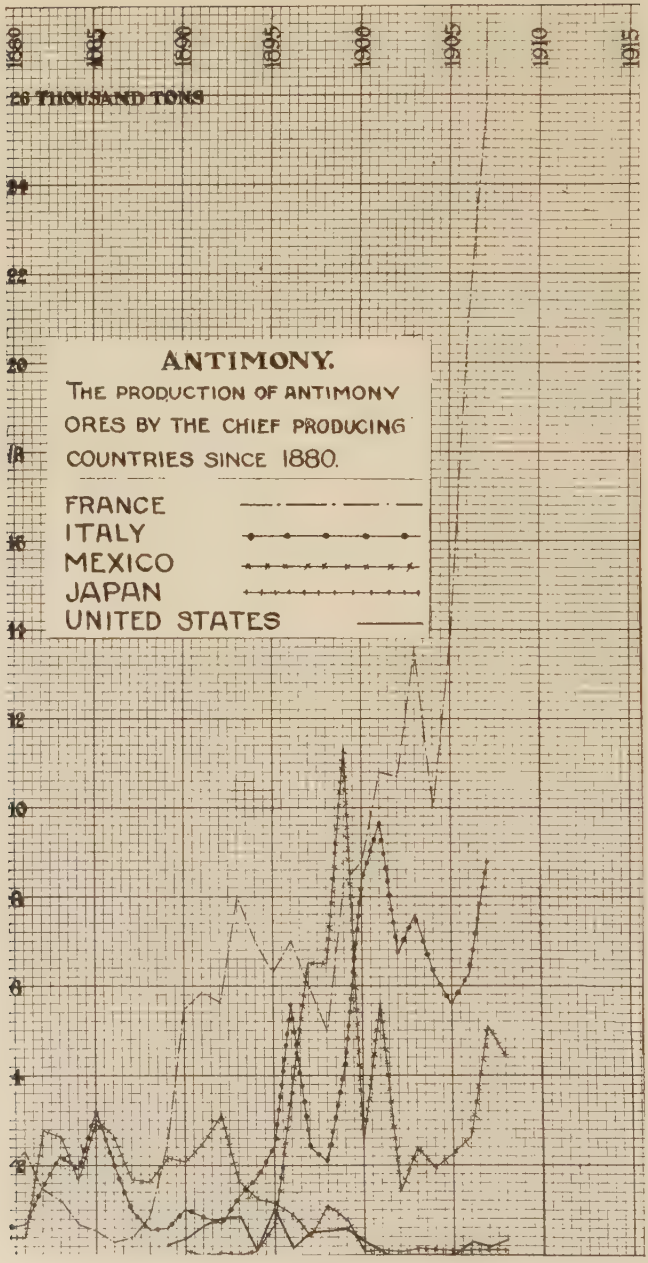
1880
1885
1890
1895
1900
1905
1910
1915
26 THOUSAND TONS
24
22
20
18
16
14
12
10
8
6
4
2
ANTIMONY.
THE PRODUCTION OF ANTIMONY ORES BY THE CHIEF PRODUCING COUNTRIES SINCE 1880.
FRANCE
ITALY
MEXICO
JAPAN
UNITED STATES

Fig. 96.

BISMUTH.

Bismuth is white with a red tinge, very brittle, and melts at 264° C.

Uses.

In medicine and cosmetics.

Its principal use is as an alloy; its alloys melt at low temperatures and expand upon cooling.

Alloys of bismuth, lead, and tin fuse at very low temperatures.

Newton's fusible metal melts at 94.5° C.

Darcet's metal melts at 93° C.

Rose's metal melts below 100° C.

Lipowitz's metal contains cadmium and melts at a little over 60° C.

The alloys are used for making safety plugs in boilers, for which they are untrustworthy, and for automatic fire plugs in buildings.

Ores.

Native bismuth is a heavy, very soft, white metal, and this is the source of most of it.

Bismuthinite, bismuth tri-sulphide ($Bi_2 S_3$), bismuth 81.2, sulphur, 18.8; bismutite, a basic bismuth carbonate, and tetradymite, a telluride of bismuth, are other forms of bismuth minerals.

Occurrence.

Bismuth usually occurs in quartz veins in granite and metamorphic rocks. It is usually associated with molybdenite, silver, cobalt, nickel, and the members of its chemical group.

Distribution.

Most of the bismuth of commerce comes from Saxony, Australia,[1] Peru, and Bolivia.

Bolivia exports from 200 to 600 tons per annum.

United States.

Bismuth occurs in the Rocky Mountains with silver ores, but the deposits have so far proved of no commercial importance.

The best known localities are: Colorado, the Bismuth Queen lode near Golden; Utah, west of Beaver City; Arizona, near Tucson.

In 1885 the United States produced only about one ton of bismuth; in 1907 it produced four tons; in 1908 it produced two tons.

[1]E. F. Pittmann.—The mineral resources of New South Wales. 256-272. Sydney, 1901.

J. A. Watt.—Notes on the occurrence of bismuth ores in New South Wales. Mineral Resources (of N. S. Wales), no. 4. Sydney, 1898.

CADMIUM.[1]

Cadmium is a ductile, malleable metal, somewhat harder than tin, with a tin-white color. When fresh it has a brilliant lustre, but dulls from oxidization upon exposure to the air. It melts at about 320° C.

Uses.

It is used as a metal only in alloys which fuse at very low temperatures.

Lipowitz's metal fuses at 60° C.

Wood's metal melts at about 66° C.

As a pigment, cadmium sulphide gives various shades of yellow.

It is also used in dentistry, glass making, photography, and pyrotechnics.

Occurrence.

Cadmium occurs as the sulphide, greenockite (CdS): cadmium 77.7, sulphur 22.3, and is found with sulphides and carbonates of zinc. It is produced with difficulty as a by-product of zinc smelting.

Distribution.

The cadmium of commerce is mostly produced in Silesia.

In 1892 the output of Silesia was 7.2 tons; in 1907 it was 35 tons; and in 1908 it was 34 tons.

In the United States cadmium is sometimes found with the zinc ores of Missouri, Kansas, Arkansas, and Pennsylvania as yellow zinc carbonate, popularly known as "turkey-fat."

The production of the United States in 1907 was 15,000 pounds; in 1908 it was 10,000 pounds.

The price of cadmium in New York was $1.25 per pound in July, 1908.

[1]W. R. Ingalls.—Zinc and cadmium. Mineral Industry, VII, 723-750. New York, 1898.

C. E. Siebenthal.—Cadmium. Mineral Resources of the United States for 1908, pt. I, 793-803. Washington, 1909.

P. Speier.—Cadmium as a by-product. Engineering and Mining Journal, LXXXVI, 538. New York, 1908.

ARSENIC.[1]

Arsenic is a brittle, grayish-white metal, that tarnishes easily; it is seldom found native.

Uses.

In medicine as tonics.

Arsenic compounds are poisonous.

Insecticides.

In preservatives of wood and biological specimens.

Alloyed with lead for shot.

As a pigment; many of the green colors contain arsenic.

Embalming fluids.

Ores.

The principal ores of arsenic are realgar (AsS): arsenic 70.1, sulphur 29.9; orpiment (As_2S_3): arsenic 61.0, sulphur 39.0; mispickel (Fe AsS): arsenic 46.0, iron 34.3, sulphur 19.7.

There are also arsenides of iron, nickel, and cobalt.

Mode of treatment.[2]

Distribution.

Arsenic is found at many places, but seldom in sufficient quantities to be mined with profit. Cornwall and Devonshire are the principal producers at present. It is also produced in Saxony and Bohemia and has been produced at Deloro, Ontario, where it occurs in gold-bearing mispickel.

[1]The Mineral Industry, II, 25-26. New York, 1894.

R. P. Rothwell.—The treatment of gold-bearing arsenical ores at Deloro, Ontario, Canada. Trans. Amer. Inst. Min. Eng., XI, 191-196. New York, 1883.

Joseph James.—Arsenic and its uses. Engineering and Mining Journal, LXXII, 4. New York, 1901.

[2]Possibilities of producing arsenic in the United States. Engineering and Mining Journal, LXXI, 656-657. New York, 1901.

Part III

The Non-Metallic Minerals
Fuels

COAL, LIGNITE, AND PEAT.[1]

National importance of coal.

The coal product of the United States in 1908 was capable of doing the work of 687,586,062 men working ten hours a day for 365 days in the year.

Uses.[2]

Domestic purposes: fuel and illuminating gas.

Steam producing: locomotives; navigation; driving machinery.

Production of electricity.

Metallurgical purposes, including the manufacture of coke.

Reduction of ores.

Iron smelting: inferior qualities of coal can not be used.

Blacksmithing.

The proportions of coal used for various purposes shown approximately by the consumption of Great Britain in 1876:

Domestic purposes, including gas, 10-40ths.

Manufacturing and locomotion, 11-40ths.

Metallurgical purposes, 15-40ths.

Exportation, 4-40ths.

The Origin of Coal.[3]

The vegetable origin of coal shown by:

Fragments of plants in the shales above and below coal beds. In some cases the impressions contain the coal made by individual plants.

[1]M. R. Campbell.—Contributions to economic geology, pt. II, Mineral fuels. Bul. 381, U. S. Geological Survey. Washington, 1910.

Contributions to economic geology, pt. II. Bul. 316, U. S. Geological Survey. Washington, 1907.

Coal and lignite. Bul. 341. U. S. Geological Survey. Washington, 1909.

[2]W. B. Clark.—Origin, distribution, and uses of coal. Maryland Geological Survey, V, 221-240. Baltimore, 1905.

[3]Leo Lesquereux.—On the vegetable origin of coal. Ann. rep. Geological Survey of Pennsylvania for 1885, 95-124. Harrisburg, 1886.

J. E. Bowman.—On the origin of coal. Trans. Manchester Geological Society, I, 90-111. Manchester, 1840.

G. H. Ashley.—The maximum rate of the deposition of coal. Economic Geology, II, 34-47, 1907.

David White.—Some problems of the formation of coal. Economic Geology, III, 292-318. 1908.

Microscopic plant fragments and spores through the coal.
Chemical composition.
Intergradation of peat and coal.

The physical conditions under which coal was deposited.[4]
Evidence of the nature of accompanying rocks.
Evidence of the accompanying fossils.
Importance of time, heat, and pressure.
The origin of anthracite coal.[5]

COMPOSITION OF COALS.
(Individual cases.)

Quality.	Water.	Sulphur.	Ash.	Fixed Carbon.	Volatile Hydro-carbon.
Lignite[6]	12.45	0.56	12.45	35.53	39.00
Lignite	30.58	0.65	9.10	28.56	31.01
Bituminous	0.70	0.86	3.56	78.99	15.87
Semi-bituminous	0.74	4.06	9.96	72.60	12.61
Anthracite	2.49	0.65	8.54	83.96	4.34

Classification by fuel ratio.[7]

Formula: Fuel ratio $= \frac{\text{fixed carbon}}{\text{volatile hydrocarbon.}}$

Bituminous	1 to 5
Semi-bituminous	5 to 8
Semi-anthracite	8 to 12
Anthracite	12 to 99

This classification may or may not hold in trade.

Effect of water in coal: objection to lignite.

Sulphur aids combustion but attacks grates and boilers, and injures pig iron.

Fixed carbon determines steaming value of bituminous coals.[8]
Influence of fixed carbon in manufacturing coke.
Volatile hydrocarbon in gas manufacture.

[4]J. S. Newberry.—On the physical conditions under which coal was formed. School of Mines Quarterly, IV, 169-173. New York, 1883.

[5]W. S. Gresley.—Observations regarding the occurrence of anthracite, with a new theory of its origin. American Geologist, XVIII, 1-21. Minneapolis, 1896.

[6]These two analyses of lignite are of the same specimen, one having been made shortly after the lignite was taken froom the Van Sickle mine, Washita Co., Arkansas, the other after it had air dried one month.

[7]M. R. Campbell.—The classification of coals. Trans. Amer. Inst. Min. Eng. XXXVI, 324-340. New York, 1906.

[8]D. T. Randall.—The purchase of coal. Bull. 339, U. S. Geological Survey. Washington, 1908.

Influence of the physical properties of coal.
Cannel coal.

Causes of the variations in character and composition of coals.[9]

Distribution.

Geologic.

The bulk of the world's coal comes from rocks of Carboniferous age, but it is also found in rocks of all ages except the oldest and the newest.

There are thin beds of coal in the Devonian; the most important beds are in the Carboniferous. Note, however, that all Carboniferous rocks do not contain coal.

Carboniferous in Belgium.[10]

Carboniferous and Permian in France.

Carboniferous and Jurassic over a large part of China.[11]

Permian coal in Australia.

Triassic coal in Virginia[14] and North Carolina.

Cretaceous and Jurassic anthracite in Peru.[12]

Cretaceous in British Columbia.

Tertiary coal on the Pacific coast of the United States and in Alaska.

Geographic.

The largest coal fields are those of China; they are but little known.[11]

The greatest coal-producing countries at present are the United States, Great Britain, and Germany; in 1908 these countries produced 81 per cent of the coal of the world.

The Coal Deposits of North America.[13]

The Carboniferous coals are the most abundant and most important.

The workable beds of Carboniferous coal cover an area of 193,000 square miles of the United States.

The Carboniferous geography of the United States.

[9]M. R. Campbell.—Varieties of coal. Economic Geology, I, 26-33. 1906.

[10]R. Malherbe.—De la richesse et de la division du système houiller de la province de Liège. Ann. Soc. Géol. de Belgique, VIII, 27-421. Liège, 1880-1.

G. Simoens.—Bul. Soc. Belge de Géol., XVI, 182-190. Bruxelles, 1902.

[11]N. F. Drake.—The coal fields of northeastern China. Trans. Amer. Inst. Min. Eng., XXXI, 492-512. New York, 1902.

N. F. Drake.—The coal-fields around Tsê Chou, Shansi, China. Trans. Amer. Inst. Min. Eng., XXX, 261-277. New York, 1901.

[12]Wm. Griffith.—Anthracite coal in Peru. Journal of the Franklin Institute, CXLVII, 227-244. Philadelphia, 1899.

Fig. 97.

Relations of the anthracite to the bituminous coal fields.

The Triassic coal of Virginia,[14] North Carolina, and Mexico.[15]

Coal of Cretaceous age in Mexico,[16] Vancouver,[17] Colorado, Wyoming, North Dakota,[18] Montana,[19] and California.[20]

[13]Arthur Winslow.—Geology of the coal regions of Arkansas. Ann. rep. of State Geological Survey for 1888. Little Rock, 1888.

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C. A. Ashburner.—Report of progress in the anthracite region. Report AA of the Second Geological Survey of Pennsylvania. Harrisburg, 1883.

I. The Pittsburg coal region. III. Anthracite coal region. Ann. rep. of the Geological Survey of Pennsylvania for 1886. Harrisburg, 1887.

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White, Campbell, and Haseltine.—The northern Appalachian coal fields. Twenty-second rep. U. S. Geological Survey, pt. III, 199-225. Washington, 1902.

C. W. Hayes.—The southern Appalachian coal field. Twenty-second ann. rep. U. S. Geological Survey, pt. III, 227-263. Washington, 1902.

[14]N. S. Shaler and J. B. Woodworth.—Geology of the Richmond basin, Virginia. Nineteenth ann. rep. U. S. Geological Survey, pt. II, 385-519. Washington, 1899.

[15]E. T. Dumble.—Triassic coal . . . . of Sonora, Mexico. Bul. Geol. Soc. Amer., XI, 10-14. Rochester, 1900.

[16]E. Ludlow.—The coal-fields of Las Esperanzas, Coahuila, Mexico. Trans. Amer. Inst. Min. Eng., XXXII, 140-156. New York, 1902.

[17]W. M. Brewer.—The British Columbia coal fields. Engineering and Mining Journal, LXXIII, 408-410; LXXIV, 180-181. New York, 1902.

[18]A. G. Leonard.—Geology of southwestern North Dakota with special reference to the coal. 5th Biennial report of State Geological Survey of North Dakota, 27-114. Bismarck, 1908.

[19]C. A. Fisher.—Geology of the Great Falls coal field, Montana. Bul. 356, U. S. Geological Survey. Washington, 1909.

J. P. Rome.—Montana coal and lignite deposits. Bul. 37, Geol. Series 2, University of Montana publications. Missoula, 1906.

[20]Peckham and Goodyear.—California and Pacific Coast coals. Geology of California, Appendix II. Cambridge, 1882.

Folio 9. Anthracite—Crested Butte Folio, Colorado. Geologic Atlas of the United States. U. S. Geological Survey. Washington, 1894.

H. W. Fairbanks.—Coal beds of California. Engineering and Mining Journal, LXII, 10. New York, 1896.

Tertiary coal about Puget Sound, in Oregon,[21] Arkansas[22] Texas,[23] Alaska,[24] and the Philippine Islands.[25]

Structural Features of Coal Regions.

Coal itself occurs in beds, not in veins, properly speaking.

Structural features of coal geology vary from nearly horizontal beds to highly folded, faulted, and eroded ones.

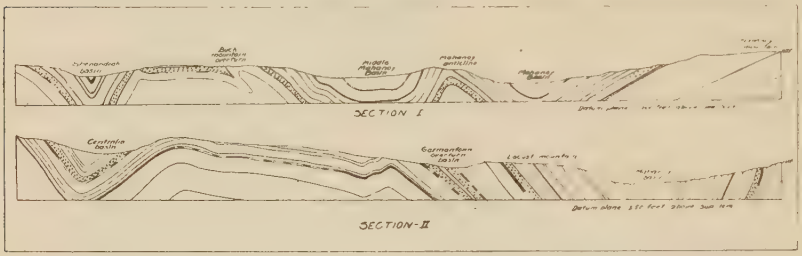

Fig. 98.—Sections showing the folds of the coal and of the accompanying beds in the Mahanoy-Shamokin basin. Schuylkill county, Pennsylvania. (Second Geol. Sur. Pa.)

[21]W. A. Goodyear.—The coal mines of the western coast of the United States. New York, 1879.

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J. S. Diller.—(Coal in Oregon). Geological reconnoissance in northwestern Oregon. Seventeenth ann. rep. U. S. Geological Survey, pt. I, 490-508. Washington, 1896.

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Geo. O. Smith.—The coal fields of the Pacific coast. Twenty-second ann. rep. U. S. Geological Survey, pt. III, 473-513. Washington, 1902. (Bibliography.)

[22]Joseph A. Taff.—The Camden coal fields of southwestern Arkansas. Twenty-first ann. rep. U. S. Geological Survey, pt. II, 313-329. Washington, 1900.

[23]W. B. Phillips.—Coal, lignite, and asphalt rocks (of Texas). Bul. No. 3, University of Texas Min. Survey. Austin, 1902.

[24]W. H. Dall.—Coal and lignite of Alaska. Seventeenth ann. rep. U. S. Geological Survey, pt. I, 771-907. Washington, 1896.

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[25]W. D. Smith.—The geology of the Compostella-Danas coal field. Philippine Journal of Science, II, 377-405. Manila, 1907.

W. D. Smith.—The coal deposits of the Philippines. Bul. 5, Bureau of Mines, P. I. Manila, 1905.

C. H. Burrit.—The coal measures of the Philippines. War Dept. 269. Washington, 1901.

J. B. Dilworth.—Philippine coal-fields. Trans. Amer. Inst. Min. Eng., XXXIX, 653-664. New York, 1909.

In the bituminous regions of the United States the beds are mostly horizontal; in the anthracite regions they are much folded; in Scotland they are extensively faulted. In Belgium they are folded and parted and are overlapped by Cretaceous and Tertiary rocks. The Belgian coal fields are the continental extension of the English coal fields.

Origin of the outliers in regions of horizontal beds.

Separation of coal fields in folded areas.[26]

Relations of dip and folds to development.

Splitting of beds; washouts.[27]

Surface and underground features in glaciated areas.

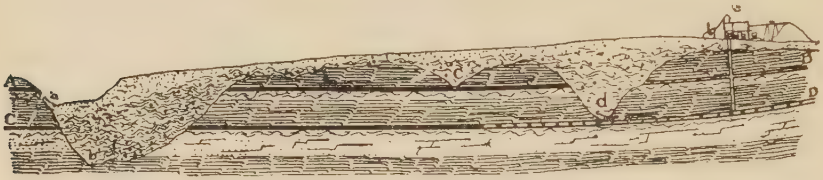

Fig. 99.—Geologic section in the glaciated part of the coal region of Indiana, showing how outcrops are mostly concealed by glacial drift. (Ashley.)

Danger from pot-holes; the Nanticoke disaster.[28]

Rocks associated with coal.

Conglomerates and their relations to the coal.

Sandstones; lithologic characters not important.

Shales are common, but they are not confined to coal-bearing horizons.

What is meant by "coal blossom."

The Coal Supply.

The structural features of coal regions make it possible to compute the approximate available coal supply.

Consumption of coal in the United States.

Increase of output, past and future.

Difficulties of determining the period of exhaustion owing to:

Possibility of working thinner beds.

Decreasing loss through better methods of mining.

Possibility of utilizing other sources of energy, such as petroleum, natural gas, and waterpower available through electric transmission over long distances.

[26]N. S. Shaler.—On the original connection of the eastern and western coal fields of the Ohio valley. Mem. Museum Comparative Zoology, XVI. Cambridge, 1887.

G. H. Ashley.—Were the Appalachian and eastern interior coal fields ever connected? Economic Geology, II, 659-666. 1907.

[27]F. E. Middleton.—On the washouts in the middle coal measures of south Yorkshire. Quar. Jour. Geol. Soc., LXI, 339-344. London, 1905.

[28]C. A. Ashburner.—The geological relations of the Nanticoke disaster. Trans. Amer. Inst. Min. Eng., XV, 629-644. New York, 1887.

Waste of Coal.

Not more than 10 per cent of the energy of coal is utilized.

The amount of coal in the world is limited, and all unnecessary waste should be avoided.

Waste of using through loss of heat; imperfect combustion.[29]

Waste in getting.

In England the loss was formerly two-thirds; now it is less than one-fourth.

The coal waste commission of Pennsylvania[30] estimates the total loss in the anthracite region at from 65 to 70 per cent, and that this will be reduced to 60 per cent.

This loss is constant for the whole region, but varies greatly with individual mines and depth to which the mines are worked.

Waste in pillars, 30-45 per cent of the whole bed.

They may be saved by longwall mining.[31]

Waste in blasting.

Wedging, mining machinery.[32]

Effect of strikes on the use of machinery.[33]

Waste in sorting in the mines, 7 per cent of what is mined.

Influence of thin beds of shale in coal bed.

Waste in handling.

Breaker waste of anthracite coal, 24-32 per cent of what goes to the breaker.

The culm heaps of the anthracite regions.

Results of different methods of breaking and screening.

Gyrating screens.[34]

Waste in shipping.

Washing.[35]

[29]M. R. Campbell.—Recent improvements in the utilization of coal. Economic Geology, II, 285-289. 1907.

[30]E. B. Coxe.—Report of commission on waste of coal mining (in Pennsylvania). Philadelphia, 1893.

[31]Long wall coal mining. Engineering and Mining Journal, LXII, 487, 1896; LXIII, 350, 1897.

H. V. Hesse.—Mining methods for the maximum recovery of coal. Engineering and Mining Journal, LXXXVII, 303-309. New York, 1909.

[32]E. W. Parker.—Coal cutting machinery. Trans. Amer. Inst. Min. Eng., XXIX, 405-459. New York, 1900

Robert Peele.—Coal cutting machinery. School of Mines Quarterly, XXXI, 1-25. New York, 1909.

[33]E. W. Parker.—Recent development in the undercutting of coal by machinery. Bul. 45, Amer. Inst. Min. Eng., 717-748. New York, 1910.

[34]A. Winslow in ann. rep. Geological Survey of Arkansas, III, 105-109. Little Rock, 1888.

[35]E. G. Tuttle.—Arrangement of coal washing plant for treating bituminous coals. School of Mines Quarterly, XVII, 378-400. New York, 1896.

The amount of loss affected by the friability of the coal.

Waste caused by leaving behind beds that may become available in the future.[36]

Beds of anthracite under three feet in thickness are not worked in the United States. Beds of only twenty inches in thickness are worked in England.

Utilization of coal waste.

Burning culm on special grates.[37]

Made into briquettes and eggettes.[38]

Extensively used in Europe.

Filling mines with waste.[39]

Importance of stacking coal waste and other waste separately.

Lignite is made into briquettes.[40]

Utilization of peat.[41]

Synthetical coal.[42]

[36]W. L. Hamilton.—Recovering abandoned coal pillars. Engineering and Mining Journal, LXXXVIII, 22-24. New York, 1909.

[37]John R. Wagner.—Burning anthracite culm. Cassier's Magazine, IX, 1-26. November, 1895.

A. D. Smith.—The yield of the Reynolds anthracite culm bank. Engineering and Mining Journal, LXVII, 440-441. New York, 1898.

[38]C. Archibald.—Patent fuel and its manufacture. Jour. Fed. Can. Min. Inst., II, 288-292. Ottawa, 1897.

R. Schorr.—Briquetting and peat fuel. Engineering and Mining Journal, LXXIV, 714. New York, 1902.

E. W. Parker.—Coal briquetting in the United States. Trans. Amer. Inst. Min. Eng., XXXVIII, 581-620. New York, 1908.

[39]Wm. G. Griffith.—Flushing of culm in anthracite coal mines. Jour. Franklin Inst., CXLIX, 271-282. Philadelphia, 1900.

[40]E. Waller and H. S. Renaud.—Lignite briquettes. Engineering and Mining Journal, LXXXII, 637-640. New York, 1906.

Paul Krusch.—The utilization of lignite in Germany. Mineral Industry for 1900, IX, 170-185. New York, 1901.

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[41]T. S. Hunt.—On peat and its uses. Canadian Naturalist, 2d Series I, 426-411. Montreal, 1864.

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C. E. Moss.—Peat moors of the Pennines: their age, origin, and utilization. Geog. Jour., XXIII, 600-671. London, 1904.

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C. A. Davis and E. S. Bastin.—Peat deposits of Maine. Bul. 376, U. S. Geological Survey. Washington, 1909.

A. L. Parsons.—Peat: its formation, uses and occurrence in New York. Twenty-third rep. State Geologist of New York, 15-88. Albany, 1903. (Bibliography.)

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C. A. Davis.—Peat as a source of chemical products. Economic Geology, V, 36-58. Jan., 1910.

[42]G. M. Randall.—Synthetical coal. Engineering and Mining Journal, LXXI, 427 and 525. New York, 1901.

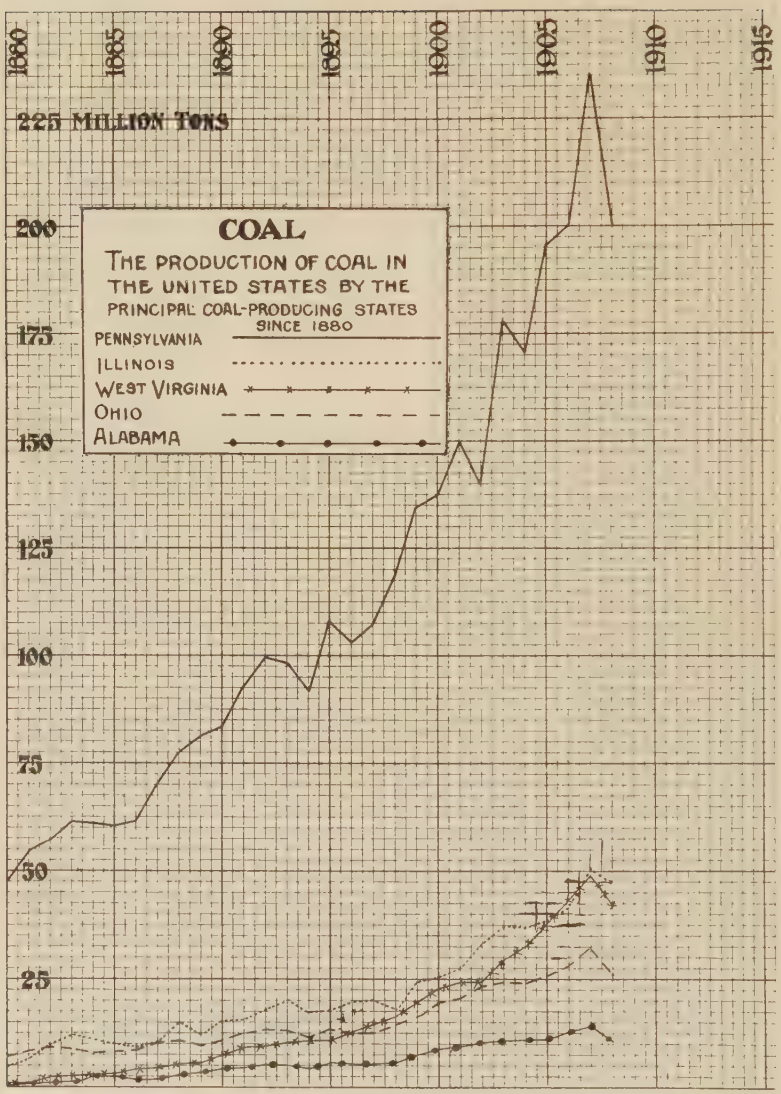

1880
1885
1890
1895
1900
1905
1910
1915
225 MILLION TONS
200
175
150
125
100
75
50
25
COAL
THE PRODUCTION OF COAL IN THE UNITED STATES BY THE PRINCIPAL COAL-PRODUCING STATES SINCE 1880
PENNSYLVANIA
ILLINOIS
WEST VIRGINIA
OHIO
ALABAMA

Fig. 100.

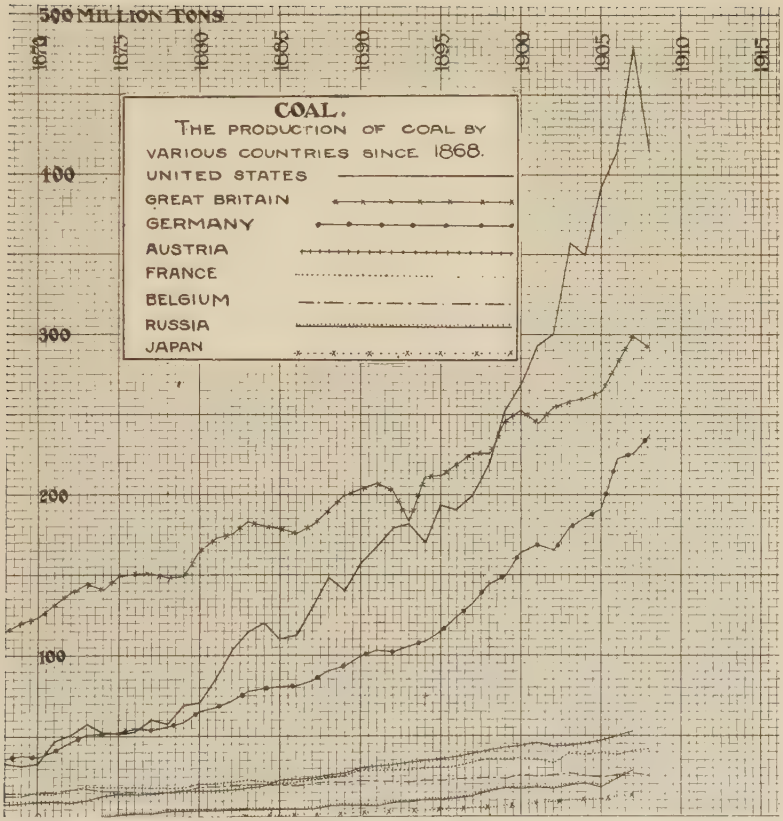

500 MILLION TONS
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
COAL.
THE PRODUCTION OF COAL BY VARIOUS COUNTRIES SINCE 1868.
UNITED STATES
GREAT BRITAIN
GERMANY
AUSTRIA
FRANCE
BELGIUM
RUSSIA
JAPAN
100
300
200
100

Fig. 101.

PETROLEUM.[1]

The hydrocarbon series is natural gas, naphtha, petroleum, mineral tar, asphalt. Petroleum is formed from naphtha by loss of volatile matter and oxidation; petroleum oxidizes to mineral tar or ozokerite which further oxidizes to asphalt.

Appearance.

Black, dirty brown, and greenish.

Gravity.

Low—7 to 10 in the black oils.

High—14 to 24 in the lighter greenish oils.

Composition.

No exact chemical formula.

Carbon is the essential element.

Uses.

In its crude condition.

Lubricating, fuel, driving engines,[2] medicine, smelting,[3] roads, manufacture of linoleum.

After being refined.

Kerosene, gasoline, paraffine, for illuminating and heating, fuel for gas engines, cleaning.

Benzine for paints and varnishes.

Vaseline for medicinal and other purposes.

Naphtha.

Rhigolene, a highly volatile fluid; when atomized it produces a temperature of —9°C., and is used as a local anesthetic and as a refrigerent.

Cymogene, a freezing product.

[1]S. F. Peckham.—Report on the production, technology, and uses of petroleum and its products. Tenth Census, X. Washington, 1884.

Joseph D. Weeks.—Petroleum. Eleventh Census. Report on mineral industries, 425-578. Washington, 1892.

B. Redwood and G. T. Holloway. Petroleum, 2 vols. London and Philadelphia, 1896.

A. Jaccard.—Le pétrole, l'asphalte et le bitume au point de vue gëologique. Paris, 1895.

C. F. Mabery.—Composition of the American sulphur petroleum. Jour. Franklin Inst. Philadelphia, 1895.

Several articles by Sadtler, Peckham, and Day, in Proc. Amer. Phil. Soc., XXXVI, 93-136. Philadelphia, 1897.

[2]R. J. L. Guppy.—Quar. Jour. Geol. Soc., XLVIII, 519. London, 1892.

Edward Orton.—American Geologist, XXV, 204-210. Minneapolis, 1900. Bibliography.

[3]A. von der Ropp.—The use of crude oil in smelting. Engineering and Mining Journal, LXXV, 81-82. New York, 1903.

F. H. Oliphant.—Petroleum. Twentieth ann. rep. U. S. Geological Survey, pt. VI (continued), 1-102. Washington, 1899.

Origin.[4]

Mendeljieff's theory (1877): water in contact with hot carbides of metals, especially of iron, decomposes; oxygen unites with iron; hydrogen takes up carbon, ascends, and condenses to oil and gas.

The generally accepted theory is that oil and gas are slowly and spontaneously distilled from organic matter.[5]

Deposits of organic origin accompany the oil bearing beds.

Diatomaceous beds in California; diatoms contain oil.[6]

Geology of petroleum.

Oil and gas are found in sedimentary rocks of almost all ages.[7]

Diffused through many rocks where it is now unavailable; possibility of distilling oil-bearing shales.[8 40]

Arkansas lignite yields 30.25 gals. per ton.

Tennessee black shale yields 30 to 40 gals. per ton.

Association of gas, oil, and salt water; and the necessity of studying them together.

Essential conditions are the same in all fields.[9]

Rocks that may contain accumulations of oil and gas:

1. Conglomerates or porous sandstones as in Pennsylvania, New York, West Virginia, Kentucky.
2. Porous limestones as in Ohio and Indiana.
   Why other rocks in the same places contain no oil or gas.
   Why the Trenton limestone yields oil in some places and not in others.
3. Porous, unconsolidated sands between plastic clays and sandstones in California.

[4]O. C. D. Ross.—The origin of petroleum. Geol. Magazine, VIII, 506-508. London, 1891.

Leopold Singer.—Beiträge zur Theorie der Petroleumbildung. Wien, 1893.

Richard Anderson.—On the origin of petroleum. Trans. Geol. Soc. Glasgow, IV, 174-177. Glasgow, 1874.

Wm. Brannt.—Petroleum: its history, origin, occurrence, etc. Philadelphia, 1895.

D. J. Day.—The conditions of accumulation of petroleum in the earth. Brit. Amer. Inst. Min. Eng., no. 42, 467-472. June, 1910.

Eugene Coste.—Volcanic origin of oil. Trans. Amer. Inst. Min Eng., XXXV, 288-297. New York, 1905.

[5]Edward Orton.—Geological probabilities as to petroleum. Bul. Geol. Soc. America, IX, 85-100. Rochester, 1898.

[6]W. Osler.—Canadian Diatomacae. Canadian Naturalist, V, new series, 142-151. Montreal, 1870.

[7]J. Wanner.—List in Geologische Rundschau, I, 24-26. 1910.

[8]I. I. Redwood.—A practical treatise on mineral oils and their by-products. London and New York, 1897.

[9]W. Topley.—The geology of petroleum and natural gas. Geological Magazine, VIII, 508-511. London, 1891.

Origin of the porosity of sandstone; porosity of limestone due to dolomitization; joint cavities in shales.

Importance of overlying impervious beds to confine oil and gas.

Relations of structure to accumulations of oil and gas.[10]

Accumulations are local and do not occur wherever any particular rock is found.

Why oil and gas accumulate in some places and not in others.

T. S. Hunt's anticlinal theory of oil.[11]

Why anticlines are only locally productive.

How monoclines may serve the same purpose.

Influence of gentle and violent folds.

How folds are recognized and located.

Oil deposits found in highly disturbed areas are usually pockety, and their distribution is difficult to determine.

Conditions essential to oil accumulations:

1. Source from which the oil may be distilled.
2. Adjacent porous rocks to hold the oil.
3. Impervious cover to prevent its escape.
4. Structural features favoring accumulations.

Surface indications, what they are and what they mean.

Factors concerned in quantity, quality, and depth of oil accumulations.

Where petroleum and natural gas are not to be sought.

1. Crystalline or eruptive rocks.
2. Rocks not associated with a possible source of supply.
3. Rocks whose structural position precludes the accumulation of a distilled product from some associated carbon bearing rock.

Rock pressure of oil and gas.

In western Ohio rock pressure is from 650 pounds to the square inch down; usually between 300 and 400 pounds.

In Indiana it is from 325 to 250 pounds.

[10]F. G. Clapp.—A proposed classification of petroleum and natural gas fields based on structure. Economic Geology, V, 503-521. Sept., 1910.

[11]I. C. White.—Petroleum and natural gas. West Virginia Geological Survey, I, 123-378. Morgantown, 1899.

T. Sterry-Hunt.—Sur les pétroles de l'Amérique du Nord. Bul. Soc. Géol., France, 2me ser. XXIV, 570-573. Paris, 1867.

T. S. Hunt.—Notes on the history of petroleum or rock oil. Canadian Naturalist, VI, 241-255. Montreal, 1861.

I. C. White.—The "anticlinal theory" of natural gas. Bul. Geol. Soc. Amer., III, 204-216. Rochester, 1892.

Practical demonstration of truth of this theory in Bul. U. S. Geological Survey, 309, 321, 322, 357, 396, 398, 406. Washington, 1907-1910.

M. J. Munn.—Studies in the application of the anticlinal theory of oil and gas accumulation. Economic Geology, IV, 141-157. Mar., 1909.

M. J. Munn.—The anticlinal and hydraulic theories of oil and gas accumulation. Economic Geology, IV, 509-529. 1909.

In Pennsylvania and West Virginia it has been recorded as high as 1,000 pounds.

The highest pressure reported is 1,525 in New York state.

Origin of rock pressure.[12]

Lesley's theory of the expansion of gas.

Orton's theory of hydrostatic pressure through the Trenton rocks that outcrop on Lake Superior.

Orton's law: *Rock pressure of Trenton limestone gas is due to a saltwater column measured from about 600′ a. t. to the level of the stratum yielding gas.*

How practically demonstrated.

Why oil wells of Pennsylvania are "watered out."

Applicability of this law modified to other territories.

Decrease of rock pressure.

In Indiana the average pressure was originally 325 pounds in 1888; in 1897 it was 191 pounds; in November, 1898, it was 173 pounds.[13]

Artificial pressure is now used to distribute gas which has been collected in large tanks; it is also used to force oil to the top of well from bottom.

Rock pressure suggests that gas and oil cannot rise from the beds in which they accumulated except when the rocks are faulted or otherwise opened.

Distribution Petroleum in the United States.

The salt industry was the forerunner of the petroleum industry.

Boring for salt water; early drill; seed bag.

High price of whale oil.

Oil from cannel coal and shale.[14]

[12]J. P. Lesley.—Consideration of the pressure, composition, and fuel value of rock gas. Ann. rep. Geological Survey of Pennsylvania, 657-680. Harrisburg, 1886.

Edward Orton.—Origin of the rock pressure of natural gas in the Trenton limestone of Ohio and Indiana. Bul. Geol. Soc. of America, I, 87-98. Rochester, 1890.

A. M. Miller.—Hydrostatic vs. lithopiestic theory of gas well pressure. Science, new series, XI, 192-193. New York, 1900.

[13]Twenty-third ann. rep. Geol. and Nat. Hist. Survey of Indiana, 1898. Indianapolis, 1899.

[14]J. C. Branner.—The oil-bearing shales of the coast of Brazil. Trans. Amer. Inst. Min. Eng., XXX, 537-553. New York, 1901.

The oil shales of the Lothians, Scotland. Engineering and Mining Journal, LXX, 754. New York, 1900.

Robt. Dunlop.—The shale oil works of Orepuki, New Zealand. Engineering and Mining Journal, LXXII, 40-41. New York, 1901.

E. F. Pittmann.—Kerosene shale. Mineral Resources of New South Wales, 358-367. Sydney, 1901.

The principal petroleum regions in the United States.

I. The Pennsylvania-New York-West Virginia region.

E. L. Drake's successful effort to get oil by boring at Titusville, Pa., in 1859.[15]

Low price from over-production.

Spouting wells or gushers.

Spread of exploration into Pennsylvania.[16]

New York.[17]

West Virginia.[18]

The Pennsylvania oil field centers at Oil City; the West Virginia field at Sisterville.

First considerable flowing well was struck in 1861, yielding 300 barrels a day.

Phillips' well yielded 3,000 barrels a day. A well near Bradford that yielded 25,000 barrels in 1875, produced 6,500,000 in 1878, and 23,000,000 in 1881.

6,358 wells were put down in 1890.

In 1903, 16,232 wells were bored and of these 13,343 became producing wells. This is 14 per cent increase over the producing wells of 1902.

II. The Ohio-Indiana region.[19 20]

The Ohio fields center at Lima; the Indiana fields center at Montpelier.

Oil and gas are from Trenton limestone in those states.

Confined by the overlying Utica shale.

[15]J. S. Newberry.—The first oil well. Harper's Magazine, LXXXI, 723-729. Oct., 1890.

[16]J. F. Carll.—Oil and gas fields of Western Pennsylvania. Geological Survey of Pennsylvania. Harrisburg, 1890.

J. F. Carll.—Report on the oil and gas regions. Part II, ann. rep. Geological Survey of Pennsylvania, for 1886. Harrisburg, 1887.

A. S. Bolles.—Petroleum; its production and products in Pennsylvania. Ann. rep. Bureau of Industrial Statistics, 1892. Harrisburg, 1893.

[17]E. Orton.—Petroleum and natural gas in New York. Bul. 30, New York State Museum, 128. Albany, 1900.

[18]I. C. White.—Petroleum and natural gas. West Virginia Geological Survey, I. 1904.

[19]J. A. Bownocker.—The oil and gas-producing rocks of Ohio. Journal of Geology, X, 822-838. 1902.

J. A. Bownocker.—The occurrence and exploration of petroleum and natural gas in Ohio. Geological Survey of Ohio, 4th series, Bul. 1. Columbus, 1903.

[20]Edward Orton.—Report of the Geological Survey of Ohio. Vol. VI, Economic geology. Columbus, 1888.

A. J. Phinney.—The natural gas fields of Indiana. Eleventh ann. rep. U. S. Geological Survey, 617-742. Washington, 1891.

E. Orton.—Origin and accumulation of petroleum and natural gas. First ann. rep. Geological Survey of Ohio, 55 et seq. Columbus, 1890.

E. Orton.—Petroleum, natural gas, and asphalt rock in western Kentucky. Frankfort, 1891.

The rocks are gently folded.

In 1889 single wells in Ohio began with a yield of 10,000 barrels a day.

III. The Illinois region.[21]

The chief producing localities are Clark, Crawford, Cumberland, and Lawrence counties, in the southeastern part of Illinois.

Small isolated, but unimportant, pools have been found in other parts of the state.

The oil is from Carboniferous sandstones or sandy shales, capped by impervious strata of close-grained Carboniferous shale.

The rocks are very gently folded.

The presence of oil was discovered in the early sixties, but was thought to be of no importance, and attempts to develop it were abandoned.

The development has been rapid since 1904.

The depth of the wells varies from 300 to 2,000 feet.

In 1908, Illinois ranked third among the states in the quantity and second in the value of petroleum produced.

PRODUCTION OF THE ILLINOIS REGION.

1905.....	181,084 barrels
1906.....	4,397,050 barrels
1907.....	24,281,973 barrels
1908.....	38,844,899 barrels

IV. The Texas-Louisiana region.[22] [23]

In Texas the oil occurs in Neocene sedimentary rocks which overlie Cretaceous shales.[23]

The great Beaumont gusher[24] threw oil at times 650 feet into the air, and flowed from 100 to 500 barrels per hour.

In Louisiana the oil comes from Upper Cretaceous and Eocene rocks.[23]

[21] H. F. Bain.—Petroleum in Illinois. Engineering and Mining Journal, LXXXIII, 755-756. New York, 1907.

H. F. Bain.—Geology of Illinois petroleum fields. Economic Geology, III, 481-491. Aug.-Sept., 1908.

W. G. Burroughs.—The petroleum fields of the U S. Engineering and Mining Journal, LXXXIX, 922. New York, 1910.

W. S. Blatchley.—The petroleum industry of southeastern Illinois. Illinois State Geological Survey, Bul. 2, Urbana, 1906.

[22] W. B. Phillips.—The Beaumont oil field, Texas. Engineering and Mining Journal, LXXI, 175. New York, 1901.

W. B. Phillips.—Texas petroleum. Bul. 5 of the University of Texas. Austin, 1900.

G. D. Harris.—Oil in Texas. Science, XIII, 666-667. New York, 1901.

[23] P. J. Fishback.—Geological horizon of the petroleum in southeast Texas and southwest Louisiana. Engineering and Mining Journal, LXXIV, 476. New York, 1902.

The new oil gushers of Jennings, Louisiana. Engineering and Mining Journal, LXXIII, 860. New York, 1902.

Geology of Louisiana. 261-275. Baton Rouge, 1902.

G. D. Harris.—Oil and gas in northwestern Louisiana. Bul. 8, Geological Survey of Louisiana. Baton Rouge, 1909.

[24] A. F. Lucas.—The great oil-well near Beaumont, Texas. Trans. Amer. Inst. Min. Eng., XXXI, 362-374. New York, 1902.

V. The Oklahoma-Kansas region.[25]

The region lies within the northeastern portion of Oklahoma and the southeastern portion of Kansas.

The oil is from Carboniferous sandstones of two classes:

1. Lenticular beds which thin out and end abruptly.
2. Sandstone beds which grade into shale.

The oil bearing sandstones are capped by impervious Carboniferous black shales and limestones.

Natural gas generally overlies the oil but in the Chanute, Kansas, region the oil overlies the gas, the two being separated by about 40 feet of close-grained shale.

About 90 per cent of the oil and gas of this region comes from anticlinal folds.

In general the depth of wells varies from 500 to 2,350 feet.

The presence of oil in this region was known, through the surface seepages, prior to 1860, but little development work was done until 1903.

Oklahoma led all of the states in the quantity of oil produced during 1907 and 1908; during the same years, Kansas ranked tenth in production.

PRODUCTION OF THE OKLAHOMA-KANSAS REGION.

Oklahoma.		Kansas.	
1907.....	43,524,128 barrels	1907.....	2,409,521 barrels
1908.....	45,798,765 barrels	1908.....	1,801,781 barrels

VI. The California region.[26]

The oil originates in Eocene and Middle Miocene rocks.

[25]E. Haworth.—The Chanute oil-fields in Kansas. Engineering and Mining Journal, LXXIV, 477-478. New York, 1902.

Chas. N. Gould.—Extent and importance of Oklahoma oil fields. Mining Science, LVII, 73-74. Denver, 1908.

G. I. Adams, E. Haworth, and W. R. Crane.—Economic geology of the Iola quadrangle, Kansas. Bul. 238, U. S. Geological Survey. Washington, 1904.

G. P. Grimsley.—Oil, gas, and glass . . . . in Kansas. Topeka, 1903.

W. G. Burroughs.—The petroleum fields of the United States. Engineering and Mining Journal, LXXXIX, 922-923. New York, 1909.

D. T. Day.—Petroleum. Mineral Resources of the U. S. for 1908, II, 384-393. Washington, 1909.

F. C. Shrader and E. Haworth.—Economic geology of the Independence quadrangle, Kansas. Bul. 296, U. S. Geological Survey. Washington, 1906.

[26]W. L. Watts.—Petroleum in California. Trans. Amer. Inst. Min. Eng., XXIX, 750-756. New York, 1900.

W. L. Watts.—Oil and gas-yielding formations of Los Angeles, Ventura, and Santa Barbara counties, California. Bul. 11, Calif. State Mining Bureau. Sacramento, 1897.

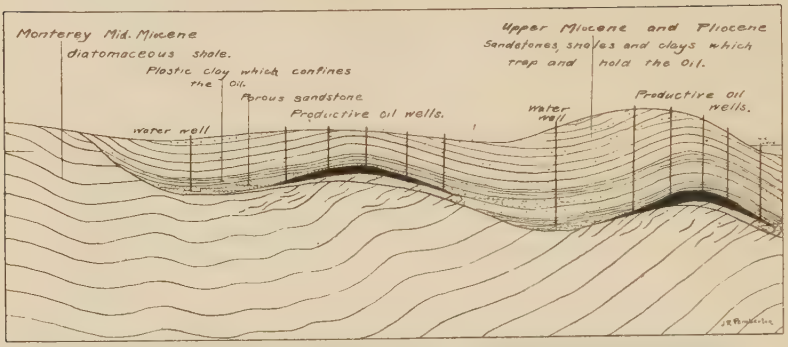
A. S. Cooper.—The genesis of petroleum and asphaltum in California. Bul. 16, Calif. State Mining Bureau. Sacramento, 1899.

W. G. Young.—The present condition of the petroleum industry in California. Engineering and Mining Journal, LXXII, 227. New York, 1901.

P. W. Prutzman.—Production and use of petroleum in California. Bul. 32, Calif. State Mining Bureau. Sacramento, 1904.

E. W. Claypole.—Notes on petroleum in California. American Geologist, XXVII, 150-159. Minneapolis, 1901.

Relations to the diatomaceous shales.



IDEAL SECTION SHOWING GEOLOGIC STRUCTURE OF THE CALIFORNIA OIL FIELDS.

Fig. 102.—The black areas represent accumulations of petroleum.

History.

Early use by the Indians; Mexicans distilled seepage products in 1855.

Drilling was done from 1865 up to 1875, but owing to poor equipments but little oil was obtained.

In 1887 only four companies were operating.

Recent development began in 1892; the greatest development from 1900 to the present.

Producing districts of California.

1. The Sunset, Midway, and McKittrick districts.[27]

The district has been known since 1856. Its first important development was begun in 1892.

The oil is in the Upper Miocene, Pliocene, and Quarternary beds, having been derived from the underlying diatomaceous Monterey shales.

Average wells give from 100 to 200 barrels per day at the start. The Lakeview gusher at Maricopa came in at 40,000 barrels per day and continued for several months.

2. The Coalinga district.[28]

The oil originates in Tertiary diatomaceous shales, and accumulates in Lower Miocene, Upper Miocene, and Pliocene beds.

[27]Ralph Arnold and H. R. Johnson.—Preliminary report on the McKittrick, Sunset oil district. Bul. 406, U. S. Geological Survey. Washington, 1910.

[28]Ralph Arnold and Robert Anderson.—Preliminary report of the Coalinga oil district. Bul. 357, U. S. Geological Survey. Washington, 1908.

Ralph Arnold and Robert Anderson.—The geology and oil resources of the Coalinga district. Bul. 398, U. S. Geological Survey. Washington, 1910.

Ralph Arnold.—Paleontology of the Coalinga district. Bul. 396, U. S. Geological Survey. Washington, 1910.

Fig. 103.—Ideal section across the Coalinga oil fields showing the oil, derived from the Tejon (Eocene) beds, confined by the later Tertiary strata. (Arnold and Anderson.)

Development commenced in 1891 and has been greatest since 1901.[29]

3. Ventura county, Los Angeles, Whittier, and Salt Lake districts.[30]
   Small fields which are separated but are geologically similar. The oil originates in the Monterey Middle Miocene shales and accumulates in the Pliocene beds.
   Development since 1892, but principally since 1900.
4. The Santa Maria oil district.[31]
   Prospecting was first done in 1899; rapid development since 1904.
   The oil has accumulated in the original organic shales and in later Pliocene beds.
5. The Summerland district.[32]
   The origin of the oil is similar to that in other California oil fields.
   The oil accumulates in Pliocene strata which are under the ocean, and wells have been sunk from piers built out over the water.
   The first well was bored in 1877, but active exploration was between 1891 and 1895.
   These wells are usually small producers.
6. The Kern River oil district.

VII. Minor oil regions.

Colorado at and south of Florence; a productive area of 14 square miles; the oil from the Fox Hills division of the Upper Cretaceous.[33]

[29]W. G. Young.—The Coalinga oil fields. Engineering and Mining Journal, LXXI, 403. New York, 1901.

[30]G. H. Eldridge and Ralph Arnold.—The Santa Clara valley, Puente hills, and Los Angeles oil districts. Bul. 309, U. S. Geological Survey. Washington, 1907.

[31]Ralph Arnold and Robert Anderson.—Preliminary report on the Santa Maria oil district, Santa Barbara county, California. Bul. 317, U. S. Geological Survey. Washington, 1907.

Ralph Arnold and Robert Anderson.—Geology and resources of the Santa Maria oil district, Santa Barbara county, California. Bul. 322, U. S. Geological Survey. Washington, 1907.

[32]Ralph Arnold.—The geology and oil resources of the Summerland district. Bul. 321, U. S. Geological Survey. Washington, 1907.

W. G. Young.—Submarine oil wells in California. Engineering and Mining Journal, LXXI, 54. New York, 1901.

[33]C. W. Washburn.—The Florence oil field, Colorado. Bul. 381, U. S. Geological Survey, 517-544. Washington, 1910.

At Rangeley the oil is from Upper Cretaceous shales and accumulates in overlying sandstones of the same age.[34]

Wyoming district.[35]

Oil occurs in the Eocene derived from Permian and Upper Cretaceous shales.

The Shoshone anticline is a northwest-southeast structural feature along which the producing territory lies.

The fields are in Uintah county.

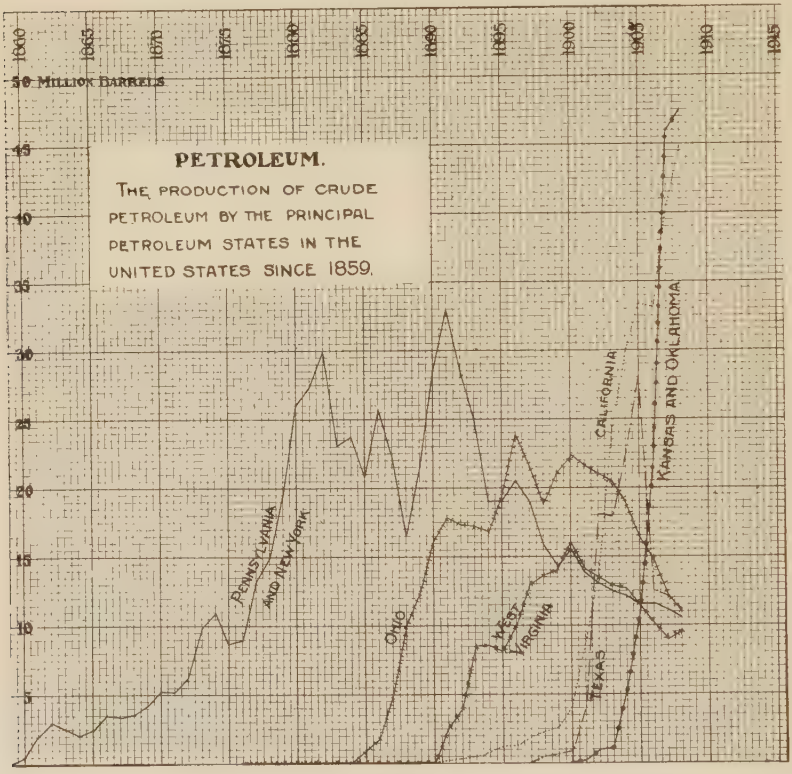


Fig. 104.

[34]H. S. Gale.—Geology of the Rangely oil district, Colorado. Bul. 350, U. S. Geological Survey. Washington, 1908.

[35]The petroleum of Salt Creek, Wyoming. Petroleum series, Bul. I of the School of Mines, University of Wyoming. Laramie, 1896.

W. C. Knight.—The petroleum fields of Wyoming. Engineering and Mining Journal, LXXII, 358-359; 628-630. New York, 1901; LXXIII, 720-723. New York, 1902.

Alaska[36] and British Columbia.

Large seepages and springs of oil and gas in the Controller Bay region.

The oil is derived from Eocene shales which contain organic matter.

Oil seepages about Cook Inlet.

The oil is from the Middle Jurrasic shales.

A little prospecting was done in 1903.

Petroleum in Other Countries.

Russia.

One of the greatest known oil fields is about Bakou on the Caspian Sea, at the southeast end of the Caucasian Mountains.[37]

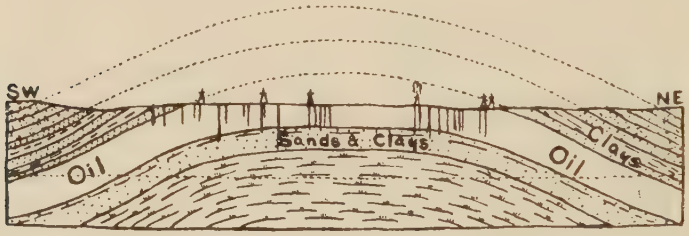


Fig. 105.—Section showing the geological structure of the oil-bearing strata in the Trans-Caucasian region, Russia. (Konchin.)

The oil is from Tertiary rocks; the wells are comparatively shallow, having averaged 715′ in 1891; formerly they were much shallower.

[36]G. C. Martin.—The petroleum fields of the Pacific Coast of Alaska. Bul. 250, U. S. Geological Survey. Washington, 1905.

Bailey Willis.—The oil of the northern Rocky Mountains. Engineering and Mining Journal, LXXII, 782-784. New York, 1901.

[37]A. Keppen.—The industries of Russia. Mining and Metallurgy, 81-90. St. Petersburg, 1893.

A. Konchin.—De Tiflis a Bakou. Gisements de naphte de Bakou. Guide des Excursions du VII. Congrès Géologique International, XXIV art. St. Petersburg, 1897.

W. F. Hume.—Baku and its oil industry. Nature, LIV, 232-234. London, 1896.

A. Beeby Thompson.—The oil fields of Russia and the Russian petroleum industry. 4th edition. London, 1904.

L. V. Dalton.—A sketch of the geology of the Baku and European oil fields. Economic Geology, IV, 89-107. 1909.

J. C. Chambers.—Petroleum trade in Russia. U. S. Consular Reports, 54, 185-197; 57, 37-50; 63, 131-150. 1897.

J. D. Henry.—Baku; an eventful history. London, 1906.

The actual oil bearing area covers only about 1,800 acres.

The product was 2,000,000 barrels in 1880; 33,355,669 barrels in 1893, and 62,186,000 barrels in 1908.

Peru and Equador. On the west coast of South America there are important oil bearing beds of Tertiary age from Payta, Peru, to north of Guayaquil in Equador.

Burma's petroleum comes from Miocene rocks.

Galicia, on the north flank of the Carpathian Mountains, produces petroleum from Tertiary rocks. The rocks are greatly folded, the wells are shallow, and the oil viscous.

Mexico.[37]

Oil on the coast of the Gulf of Mexico, in the state of Vera Cruz, originates in Tertiary diatomaceous shales.

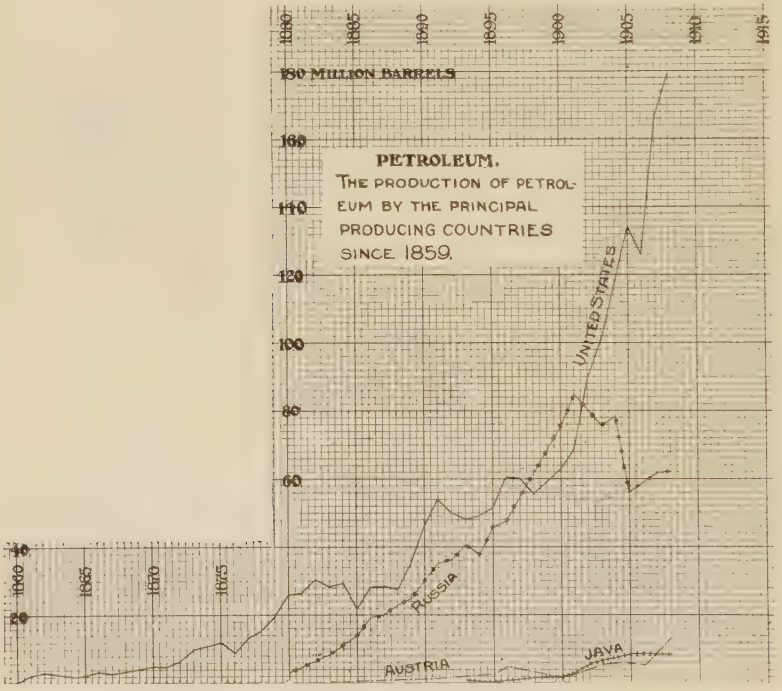


Fig. 106.

[37]S. Pearson & Son's uncontrollable oil gusher. Engineering and Mining Journal, LXXXVII, 7. New York, 1909.

Borneo.[38]

Oil occurs in folded Tertiary rocks.

Output of the Minor Oil Producing Countries.

	1898. Barrels.	1908 Barrels.
Peru	69,000	1,011,180
Galicia	2,376,108	12,611,428
Roumania	766,238	8,252,157
India	542,110	5,047,038
Japan	265,400	2,061,841
Canada	750,000	527,987
Mexico		19,207,159

Limits of the supply of petroleum.

Order of gas, oil, and water in producing wells.

Sequence of their exhaustion.

Good but dearer oil can yet be manufactured from shale.[39]

Oil shales of New Brunswick and Nova Scotia.[40]

The oil is disseminated through Upper Devonian shales which carry 42% volatile matter which can be distilled out.

Oil shales of Scotland,[41] New Zealand,[42] and of other parts of the world.

The locating of oil wells.

How far geology may be depended upon.

The elements of uncertainty.

Indications of oil in the rock; "Trenton rock;" "surface indications."

Oil may or may not appear at the surface.

Method of drilling.

Growth of deep well drilling in America.

Determining the geologic position of the drill.

Methods of labeling and preserving borings.

Importance and practical use of well records.

The depth of wells varies from two hundred feet or less to over five thousand feet according to circumstances.

[38]Carl Schmidt. Borneo. Bul. Soc. Géol. de France. 4me sér. I, 266-267. Paris, 1901.

[39]C. Baskerville.—Economic possibilities of American oil shales. Engineering and Mining Journal, LXXXVIII, 149-154; 195-197. New York, 1909.

[40]R. W. Ells.—Bituminous oil shales. Canadian Dept. of Mines. Geol. and Min. Resources of New Brunswick, nos. 983, 107-114. Ottawa, 1907; 55 and 1107. Ottawa, 1910.

[41]D. R. Steuart.—The shale oil industry of Scotland. Economic Geology, III, 573-598. 1908. (Bibliography.)

[42]A. Beeby Thompson.—Petroleum mining and oil field development. 362. London, 1910.

Wells are spaced according to amount, gravity of the oil, the character of the rock, and the cost of completing the wells.

In some rocks one well drains five acres; in others it drains fifty acres.

In some places in California there is one well to every two and a half acres; but usually one well drains five acres.

Oil and gas may be drawn from the lands of others without redress.

How torpedoes increase or decrease the flow of wells.

The transportation of petroleum.

Originally in barrels, then in tank cars; dangers and losses.

Now there are about 25,000 miles of pipe lines in the Pennsylvania fields.

Pumping from the oil fields of Pennsylvania, West Virginia, Ohio, and Indiana, through pipe lines to the sea-board at Baltimore, Philadelphia, New York, Buffalo, Cleveland, and Chicago.

In California the following pipe lines, mostly 8 inches in diameter, were in operation in January 1, 1911:

	Miles.
Waite to Point Richmond, Bay of S. F.	280.6
Midway and Kern to Port Costa	420.0
McKittrick to Waite	48.5
Coalinga to Mendota	36.8
Coalinga to Monterey Bay	108.0
Coalinga, Kern, and Midway to Avila	200.0
Santa Maria to Avila, near Port Harford	33.0
Santa Maria to Gaviota	70.0
Orcutt to Port Harford	66.0
	1,262.9

Some of these lines are double, so that the total pipe length was 1,642 miles on January 1, 1911.

Pipe lines have pumping stations from twenty-five to fifty miles apart, according to the grade. Modern pipe lines are rifled, and have the insides lubricated with water, and oil is heated at each pumping plant to increase its fluidity.

Refining petroleum.

Importance of oil due largely to its being refined.

Effect of good, cheap light on civilization.

Limestone oils contain more sulphur.

These were first used for lubricating; in 1893 most of the illuminating oils were made from these.

Special value for certain oils: lubricating; lighting; fuel.

NATURAL GAS.[1]

Natural gas is a hydrocarbon, CH_4, and generally contains impurities, such as nitrogen and sulphur. It is a distillation product from petroleum, coal, and other organic substances.

Advantages as a fuel.

Readily transported; leaves no refuse; easily ignited and regulated; boilers and furnaces last longer than when coal is used.

In 1885 natural gas about Pittsburg replaced 3,650,000 tons of coal, and displaced 5,000 men.

It replaced coal to the following values in the principal gas producing states:

	1889	1908
In Pennsylvania	$11,593,989	$19,104,944
In Ohio	5,123,569	8,244,835
In Indiana	2,002,762	1,312,507
In West Virginia	12,000	14,837,130
In Kansas	15,873	7,691,587

Modes of Occurrence.

1. In shales and limestones.
2. Reservoir gas in sandstone, conglomerates, and certain dolomitic limestones.

The relations of geologic features of natural gas to those of petroleum. Wells at the crowns of anticlinal domes last longest.

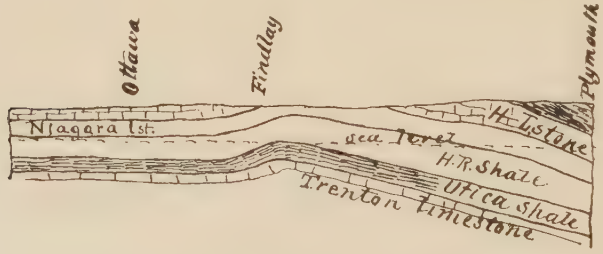


Fig. 107.—Section through Findlay, Ohio, showing the anticline at the crest of which the great oil and gas wells are located. (Orton.)

The relations of gas and water to each other in the rocks.

Small quantities of gas are of common occurrence and are of no importance.

[1]F. H. Oliphant.—Natural gas. Twentieth ann. rep. U. S. Geological Survey, pt. VI, 203-250. Washington, 1899. Twenty-first ann. rep. U. S. Geological Survey, pt. VI, 293-318. Washington, 1901.

Characteristics of Shale Gas.[2]

1. It is of comparatively small volume.
2. It lacks uniformity of pressure.[3]
3. The gas comes from no definite horizon.
4. It is often independent of the oil production.
5. It has good staying properties.
6. It is not dependent upon geologic structure.

Characteristics of Reservoir Gas.

1. The largest known wells are of this kind.
2. The pressure is uniform.
3. The gas is at definite geologic horizons.
4. Oil accompanies the gas.
5. Geologic structure is of great importance.

The Waste of Natural Gas.[4]

The store of natural gas is limited; so excellent a fuel should not be wasted.

Murraysville well in Pennsylvania played into the air for six years at the rate of 20,000,000 cubic feet of gas per day.

In 1885 the waste of gas within piping distance of Pittsburg was 70,000,000 cubic feet per day.

Gradual Exhaustion.

Only time can show how long individual wells can last.

Natural gas prepares the way for artificial gas.

The gas producing states:

In 1908 natural gas was produced in 18 states of which only 11 were important: Pennsylvania, West Virginia, Ohio, Kansas, Indiana, New York, Oklahoma, Illinois, California, Texas, and Kentucky.

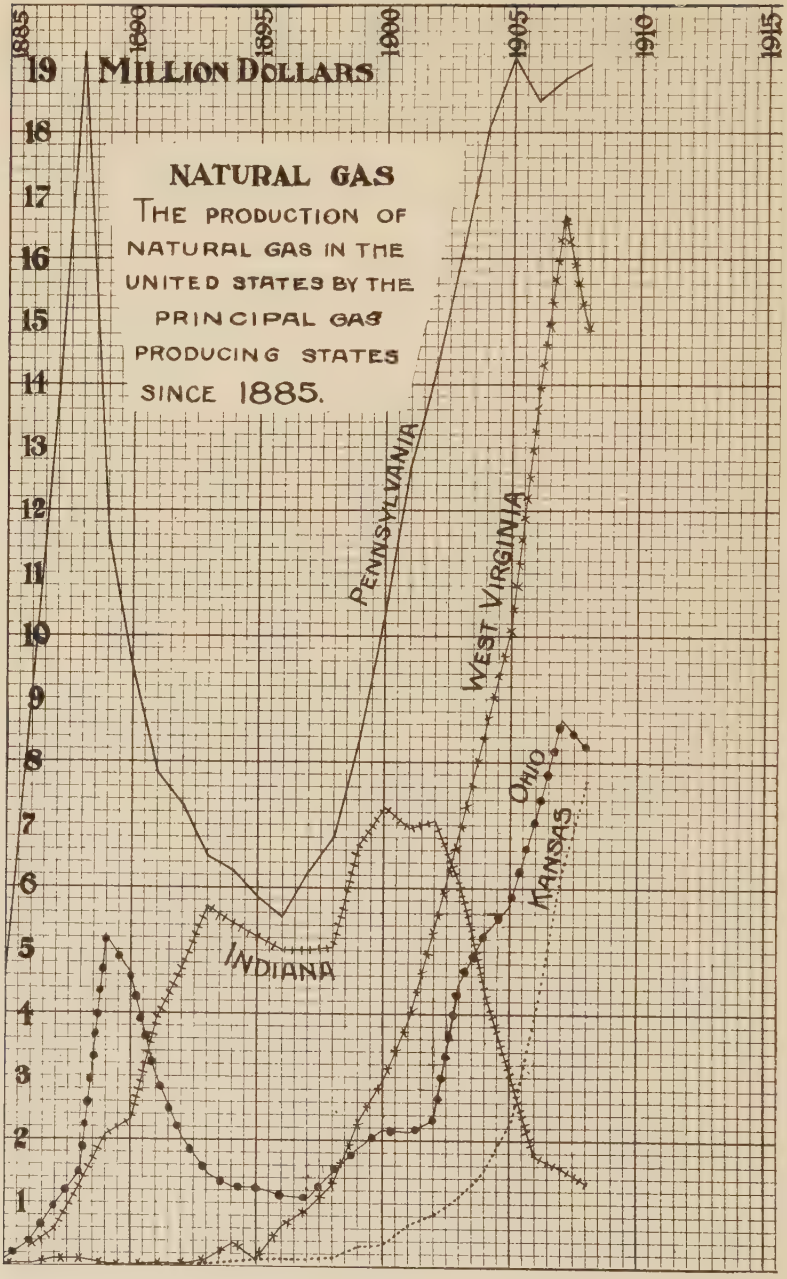
[2]Haworth and Adams.—Economic geology of the Iola quadrangle, Kansas. Bul. 238, U. S. Geological Survey. Washington, 1904.

Edward Orton.—Geological structure of the Iola (Kansas) gas field. Bul. Geol. Soc. Amer. X, 99-106. Rochester, 1899.

[3]A. M. Miller.—Hydrostatic vs. lithopiestic theory of gas well pressure. Science, new series, XI, 192-193. New York, 1900.

[4]I. C. White.—Shortage of coal in the northern Appalachian coal field. Bul. Geol. Soc. Amer., XX, 333-340. New York, 1910.

For other references to the geology of natural gas see footnotes under Petroleum in this syllabus.


1885
1890
1895
1900
1905
1910
1915
19 MILLION DOLLARS
18
17
16
15
14
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3
2
1
NATURAL GAS
THE PRODUCTION OF NATURAL GAS IN THE UNITED STATES BY THE PRINCIPAL GAS PRODUCING STATES SINCE 1885.
PENNSYLVANIA
WEST VIRGINIA
OHIO
KANSAS
INDIANA

Fig. 108.

BUILDING STONES.[1]

Nearly all kinds of stone can be used for building purposes; those most used are granites, sandstones, and limestones.

PROPERTIES TO BE CONSIDERED IN BUILDING STONES.[2]

Ability to withstand weather.[3]
Ability to withstand heat.[4]
Color.[5]
Hardness before and after being worked.
Density and porosity.
Crushing strength.

Building stones are seldom subjected to more than from one-sixth to one-tenth the pressure they can withstand.

Stone subjected to a gradual pressure can withstand more than the same stone when subjected to sudden pressure.

CRUSHING STRENGTH IN LBS. PER SQ. IN. OF TYPICAL BUILDING STONES.

Granite		Limestone		Sandstone	
East St. Cloud, Minn.	28,000 / 26,250	Conshohocken, Pa.	16,340	Belleville, N. J.	11,700 / 10,250
Mystic River, Conn.	18,125 / 22,250	Bedford, Ind.	6,500 / 10,125	Albion, N. Y.	13,500
Fourche Mt., Ark. (syenite)	33,620	Joliet, Ill.	14,775	Berea, O.	10,250
Penryn, Cal.	6,117	Quincy, Ill.	9,797	Portland, Conn.	4,945
Average of 27 Wisconsin granites and rhyolites	27,024	Average of 31 in Wisconsin.	25,313	Average of 45 in Wisconsin.	6,125

[1]W. C. Day.—Stone. Twentieth ann. rep. U. S. Geological Survey, pt. VI, continued, 269-464. Washington, 1899.

O. Herrmann.—Steinbruchindustrie und Steinbruchgeologie. Technische Geologie nebst praktischen Winken für die Verwertung Gesteinen. Berlin, 1899.

G. P. Merrill.—The physical, chemical, and economic properties of building stones. Maryland Geological Survey, II, pt. II., 47-121. Baltimore, 1898.

G. P. Merrill.—The collection of building and ornamental stones in the U. S. Nat. Museum. Smithsonian rep. 1886. pt. II, 277-648. Washington, 1889.

Report on the building stones of the United States. Tenth Census, 1880, X, 1-393. Washington, 1884.

G. P. Merrill.—Stones for building and decoration. New York, 1897.

Stone. An illustrated magazine, issued monthly. Chicago.

[2]E. R. Buckley.—The properties of building stone and methods of determining their values. Journal of Geology, VIII, 160-185. Chicago, 1900.

[3]A. A. Julien.—The decay of the building stones of New York City. Trans. N. Y. Acad. Sci., II, 67-79; 120-138. New York, 1883.

A. A. Julien.—Building-stones; elements of strength in their constitution and structure. Jour. Franklin Inst., CXLVII, 257-442. Philadelphia, 1899.

H. A. Cutting.—Durability of building stones. Amer. Jour. Sci., CXXI, 410. New Haven, 1881.

[4]W. E. McCourt.—Fire tests on some New York building stones. Bul. 100, N. Y. State Museum. Albany, 1906.

[5]J. Gemmell.—Color in architecture. Stone, XX, 428-431. New York, May, 1900.

Distribution.

Stone that may be utilized for building is found in nearly all countries, and in almost all geologic formations.

GRANITE.

Granite has an average specific gravity of 2.66, is a highly crystalline rock, varying widely in texture and color, with quartz and feldspar as essential constituents; mica and hornblende with other minerals are usually present.

There are many varieties of granite; those most in use for building purposes are biotite granite; muscovite granite; hornblende granite.

Uses.

In massive structures.

As an ornamental stone for monuments, and interior decorations.

Damage done granite buildings by fire.

Distribution.

Geological.

Granites may be of any age.

They occur massive, never stratified; often as cores of mountain ranges; sometimes as dikes.

Geographical.

Granite has a world wide distribution.

The New England states are the principal granite producers of the United States.

Vermont:

Massachusetts.[7] The quarries at Quincy are the most important; the stone is coarse grained, and usually dark blue-gray.

Maine. The granites gray (largely), pink, and red.

Largest quarries at Vinalhaven.

California[8] granite very generally distributed through the state. There are important quarries at Rocklin, Raymond, and Penryn. The stone is fine grained; the color from light gray to dark gray.

Wisconsin.[6]

[6]E. R. Buckley.—On the building and ornamental stones of Wisconsin. Bul. 4, Geological Survey of Wisconsin. 390-394. Madison, 1898.

E. R. Buckley.—Results of tests on Wisconsin building stones. Journal of Geology, VIII, 526-567. Chicago, 1900.

[7]T. N. Dale.—The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island. Bul. 354, U. S. Geological Survey. Washington, 1908.

[8]Structural and industrial materials of California. Bul. 38, Calif. State Min. Bureau. Sacramento, 1906.

Folio 5. U. S. Geological Survey, Washington, 1894.

Maryland.[9]

Rhode Island. The principal quarries are near Westerly; the rock is biotite granite, fine grained; in color from pink to light gray.

Connecticut: granite and gneiss, fine grained; color, mostly light gray.

New Hampshire has granite in the eastern part of the state; color, light gray to white; fine grained.

Georgia has light-gray granite near Atlanta.

Granite is quarried in many other states, but to a less extent.

VALUE OF GRANITE QUARRIED IN THE PRINCIPAL PRODUCING STATES.

	1898	1908
Vermont	$1,084,218	$2,451,933
Maine	1,032,621	2,027,508
Massachusetts	1,650,508	2,027,463
California	247,429	1,684,504
Wisconsin	175,867	1,529,781
Georgia	339,311	970,832
Washington	9,700	870,944
New Hampshire	683,595	867,028
North Carolina	79,969	764,272
Maryland	317,258	762,442
Minnesota	79,309	629,427
Connecticut	682,768	592,904
Rhode Island	320,242	556,474
New York	516,847	367,066
Delaware	677,754	195,761
New Jersey	753,513	125,804

LIMESTONES.

See under "Marble," and "Limestones other than marbles."

SANDSTONES.

Sandstones are fragmental sedimentary rocks occurring in all geologic formations, having quartz sand as an essential constituent. In color they vary from white to blue, brown, and red. The color and adaptability are determined largely by the cementing material. Freshly quarried sandstones are often soft, owing to the water contained, and harden upon exposure.

Sandstones vary greatly in texture and color.

They may be quartzites, flagstones, freestones, calcareous sandstones, or ferruginous sandstones.

[9] G. P. Merrill and E. B. Mathews.—The building and decorating stones of Maryland. Maryland Geological Survey, II, 47-247. Baltimore, 1898.

Geologic Relations.

Sandstones are of sedimentary origin, and subject to the conditions of other sedimentary deposits.

Sandstones in the United States.

Ohio: the most important quarries are in the Berea Grit (Lower Carboniferous) in the northern part of the state.

The stone is fine grained and the color from buff to blue.

Pennsylvania: Triassic sandstones.[10] The principal quarries are in Dauphin county. Color, "deep bluish-brown, slightly purple," with reddish-brown layers.

Connecticut: Triassic sandstone, brown and red. The quarries at Portland are the most important.

New York:[11] Cambrian sandstone (Potsdam); color, very light to light red; very hard.

Upper Silurian (Medine) sandstone; gray to red; rather coarse texture.

Devonian (Hamilton) sandstone;[12] color, "dark blue-gray;" compact, fine grained.

New Jersey: red and dark brown Triassic sandstones. Much used in eastern cities.

Other states.

Red sandstones of Colorado, Arizona, New Mexico, and California.

Snuff colored sandstones of Arkansas.

VALUE OF SANDSTONES QUARRIED IN THE CHIEF PRODUCING STATES.

	1898	1908
New York	$ 566,133	$1,774,843
Pennsylvania	478,451	1,368,784
Ohio	1,494,746	1,244,752
Washington	15,575	464,587
Arizona	27,444	396,458
California	358,908	330,214
Massachusetts	91,287	241,462
Wisconsin	80,341	219,130
Minnesota	175,810	197,184
Colorado	89,637	181,051

[10]T. C. Hopkins.—Building materials of Pennsylvania. I, Brownstones. Appendix to ann. rep. Pennsylvania State College for 1896.

[11]J. C. Smock.—Building stone in the State of New York. Bul. of the New York State Museum, no. 3. Albany, 1888.

[11]J. C. Smock.—Building stone in the State of New York. Bul. of the New York Museum, II, no. 10. Albany, 1890.

[12]H. T. Dickinson.—Bluestone and other sandstones in the upper Devonian of N. Y. State. Bul. 61, New York State Museum. Albany, 1903.

OTHER BUILDING STONES.

Conglomerates: coarse grains or pebbles held together by some cementing material; breccia is a kind of conglomerate in which the fragments are angular.

Slates:[13] metamorphosed clay shale, usually of some dark color; much used for roofing, school slates, blackboards, mantels, flagging, and billiard tables. Usually found in regions of folded rocks.

Tuff: volcanic rocks; when consolidated are sometimes used in buildings. Extensively used for ballast on the Santa Fe railway.

Gneiss in composition is the same as granite, but it shows a foliated or banded structure; it is extensively used for buildings in Brazil.

Schists in structure are somewhat similar to gneiss. The schists split readily and are much used for flagging, and sometimes in foundations.

Syenite is like granite, except that it contains no quartz. The syenite near Little Rock, Arkansas, an excellent building stone, is blue or gray in color. Average crushing strength (per sq. inch in 2-inch cubes) 33,620 lbs.[14]

Augite: a dark-colored eruptive rock, usually containing magnesium and iron, is used some for buildings, and extensively in paving.

Serpentine: a hydrous silicate of magnesia, derived from the alteration of eruptive rocks; the color is usually green or yellowish, sometimes brown, red, or almost black. The variety known as verde-antique is much used for interior decorations.

[13]T. N. Dale.—Slate deposits and slate industry of the United States. Bul. 275, U. S. Geological Survey. Washington, 1906. Bibliography.

[14]J. Francis Williams.—The igneous rocks of Arkansas. Ann. rep. Geological Survey of Arkansas for 1890, II, 42-53. Little Rock, 1891.

MARBLE.[1]

"Any limestone, whether compact, crystalline, or granular, which will receive a polish and is suitable for ornamental purposes, is considered a marble."

Uses.

Marble is usually available for all of the various uses of ordinary limestone.

Monumental and decorative interior work and statuary.

Adaptations of special colors and varieties.

Origin and Occurrence.

Marbles are mostly metamorphosed limestones, and originated as organic sedimentary beds.

Forms, structural disturbances, and changes of the beds.

Kinds of marble.

Marbles vary from mottled impure limestone to the finest and most highly crystalline white varieties, and from white through all mottled and variegated colors to black.

Statuary marble must have a perfectly uniform color and be free from flaws.

Parian marble the finest statuary marble; supply about exhausted.

Pentelican marble much used by the ancients.

Cararra marble, from the Apennines, used almost entirely by sculptors at present.[2] Color snow-white; texture saccharoidal.

Marbles of all kinds, mottled, banded, or of uniform color, are used for ordinary interior decorations. Light tints most used; black marble rare.

"Onyx" marble, a crystalline cave deposit; its beauty and scarcity.[3]

Distribution.

Marble has a very general distribution, both geologic and geographic.

FOREIGN MARBLE, PRINCIPAL PRODUCERS.

Austria, Belgium, France, Italy, Spain, and Portugal, are all rich in marbles. The Italian marbles from the Apennines, used by sculptors, are the most noted.

[1]Report of the building stones of the United States. Tenth Census, 1880, X, 1-393, with plates.

G. P. Merrill.—Stones for building and decoration, 83-166. New York, 1897.

Edward Hull.—The building and ornamental stones of Great Britain and foreign countries. London, 1872.

[2]See Baedecker's Northern Italy under "Carràra," and National Geographic Magazine, XXI, 326-329. Washington, 1910.

[3]G. P. Merrill.—Onyx-marbles. Rep. U. S. Nat. Mus. for 1893, 541-585. Washington, 1895.

Mexico formerly contained a large deposit of marble, popularly called "Mexican onyx"; this deposit is practically exhausted and most of the so-called "Mexican onyx" is now obtained from other sources.

Marble in the United States.

Vermont[4] marble is "white, clouded, or blue."
The principal quarries are at Rutland.

Tennessee[5] marble is pinkish and variegated. The beds are of Lower Silurian age, and there are extensive quarries in the vicinity of Knoxville.

Georgia[6] has the same kind of marble as that of Tennessee.

Alabama[7] has extensive deposits of unworked marble also like the Tennessee marble.

New York[8] has large quarries at Gouveneur, where the "St. Lawrence" marble is quarried.

Arkansas[9] marble is the same as that of Tennessee and Georgia.

THE VALUE OF THE PRODUCTION OF MARBLE.

	1898.	1908.
Vermont	$2,067,938	$4,679,960
Georgia	656,808	916,281
Tennessee	316,814	790,233
New York	432,072	706,858
Massachusetts	38,210	175,648
Alabama		118,580
Alaska		103,888
Pennsylvania	39,373	102,747
Maryland	120,525	79,317
California	40,200	60,408

[4]A. D. Hager.—Geology of Vermont. II, 751-780. Claremont, N. H., 1861.

[5]James M. Stafford.—Geology of Tennessee. Nashville, 1869.

[6]S. W. McCallie.—A preliminary report on the marbles of Georgia. Geological Survey of Georgia, Bul. no. 1. Atlanta, 1907.

[7]P. Bryne.—Marble formations of the Cahaba river, Ala. Engineering and Mining Journal, LXXII, 400. New York, 1901.

[8]J. C. Smock.—Building stone in the State of New York. Bul. no. 3, New York State Museum of Nat. Hist. Albany, 1888.

[8]J. C. Smock.—Building stone in New York. Bul. of the New York State Museum, II, no. 10. Albany, 1890.

[9]T. C. Hopkins.—Marbles and other limestones. Ann. rep. Geological Survey of Arkansas for 1890, IV. Little Rock, 1893.

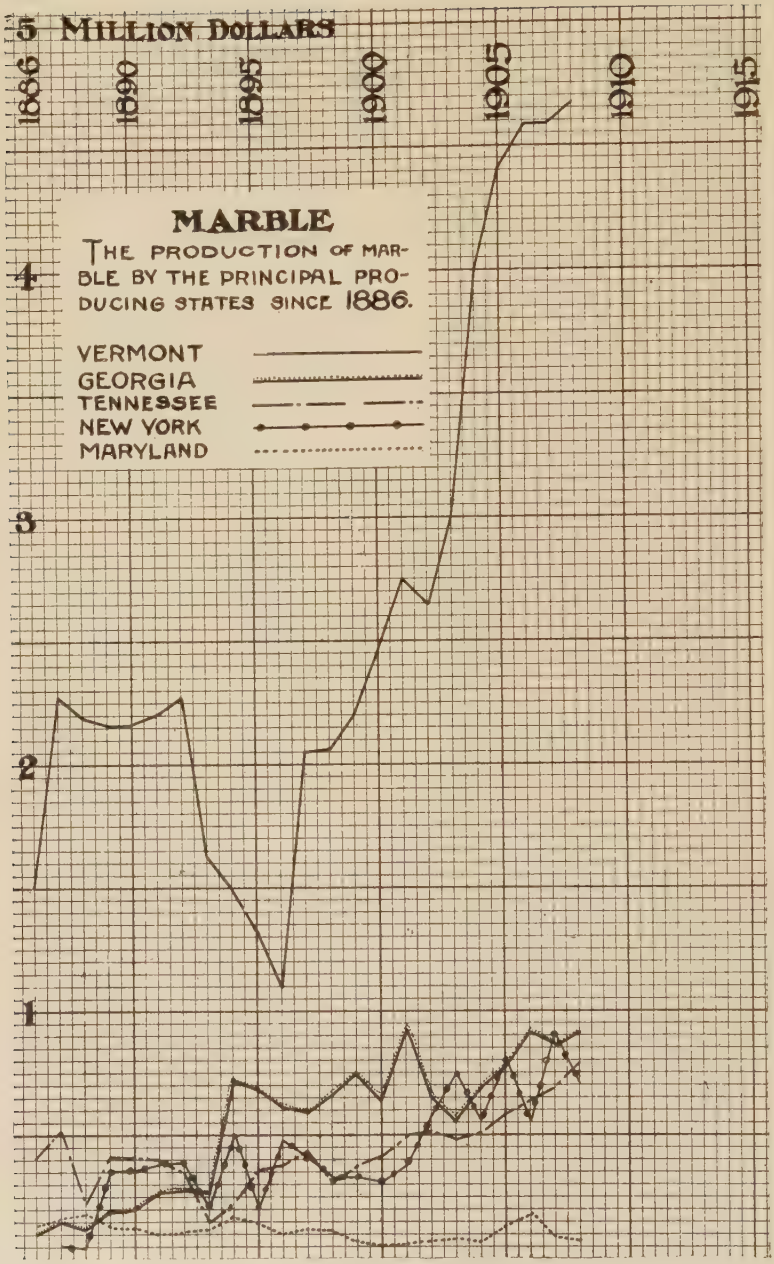
5 MILLION DOLLARS
1886
1890
1895
1900
1905
1910
1915
MARBLE
THE PRODUCTION OF MARBLE BY THE PRINCIPAL PRODUCING STATES SINCE 1886.
VERMONT
GEORGIA
TENNESSEE
NEW YORK
MARYLAND
4
3
2
1

Fig. 109.

LIMESTONES OTHER THAN MARBLES.[1]

Limestone is a sedimentary rock composed of calcium carbonate, often containing some magnesium carbonate; it always contains impurities.

Uses.

For building purposes.

Importance as a building stone.

Crushing strength of 62 samples, 14,545 pounds per square inch, ranging from about 5,000 pounds to 25,000 pounds.

As a flux in smelting ores.

Lithographing.

In the manufacture of lime and cement.

Manufacture of carbonic acid gas. Marble is generally used for this purpose.

Whiting, from chalk.

Effect of limestone on the manufacturing and agricultural wealth of a country.

Origin of Limestones.

Organic.

Rhizopods, pteropods, and heteropods over deep seas; corals, echinoderms, crustaceans, bryzoans, brachiopods, lamellibranchs, gasteropods, cephalopods in off shore or comparatively shallow waters; calcareous algae.

Chemical by precipitation from solution, as in the case of travertine deposits.

Occurrence and Distribution.

When of sedimentary origin the beds have the forms and structural characters of other sedimentary rocks.

World-wide geographic and geologic distribution of limestones.

In colors limestones vary from white to black through shades of buff and blue. They generally weather to lighter colors.

Limestones vary in character from calcareous shales and sandstones to pure limestones.

Shaly limestones; sandy limestones.

Crystalline limestones are mostly marbles.

Chalk is a soft limestone.

[1]Report on the building stones of the United States. Tenth Census, X, 1-393, with plates. Washington, 1884.
G. P. Merrill.—Stones for building and decoration, 122-166. New York, 1897.
T. C. Hopkins.—Marbles and other limestones. Geological Survey of Arkansas for 1890, IV. Little Rock, 1893.

Oölitic limestones; example, the Bedford stone of Indiana.

Lithologic limestones.

Dolomitic limestone.[2]

Dolomite is a carbonate of calcium and magnesium, with the proportions varying 1 to 1, 1 to 3, or 1 to 5.

Hydraulic limestones.

PRINCIPAL LIMESTONE PRODUCING STATES.

Pennsylvania[3] has limestones of Lower Silurian, Devonian, and Lower Carboniferous ages. They are used for building, and as a flux in smelting.

Indiana produces the well known "Bedford oölitic stone"[4] of Lower Carboniferous age, which is the most important building stone in that state. The principal quarries are in Lawrence and Monroe counties.

Ohio:[5] has limestones of Silurian, Devonian, and Carboniferous ages which are quarried in various parts of the state. They are usually dull in color and are used mostly for rough work.

Illinois: the largest quarries are in Will county at Lemont and Joliet. The rock is of Niagara age, and the stone is light drab and fine grained. The Trenton limestone of Jo Daviess county is also important.

Michigan.[6]

PRODUCTION OF LIMESTONE.

	1897.	1908.
Pennsylvania	$2,327,870	$4,057,471
Indiana	2,012,608	3,643,261
Ohio	1,486,550	3,519,557
Illinois	1,483,157	3,122,552
Missouri	1,018,202	2,130,136
New York	1,697,780	2,584,559
Wisconsin	641,232	1,102,009

[2]The origin of dolomite. American Journal of Science, CXLIX, 426-427. New Haven, 1895.

Hall and Sardeson.—(Origin of the dolomites.) Bul. Geol. Soc. America, VI, 193-198. Rochester, 1894.

[3]F. G. Clapp.—Limestones of southwestern Pennsylvania. Bul. 249, U. S. Geological Survey. Washington, 1905.

[4]W. S. Blatchley.—Oölite and oölitic limestone for the manufacture of Portland cement. 25th ann. rep. Dept. Geol. and Nat. Hist. Indiana Geological Survey, 322-330. Indianapolis, 1901.

T. C. Hopkins and C. E. Siebenthal.—The Bedford oölitic limestone of Indiana. Twenty-first ann. rep. Geological Survey, Indiana, 290-421. Indianapolis, 1896.

[5]E. Orton, Jr. and S. V. Peppel.—The limestone resources and the lime industry in Ohio. 4th ser. Bul. 4, Geological Survey of Ohio. Columbus, 1906.

[6]A. C. Lane.—Michigan limestones and their uses. Engineering and Mining Journal, LXXI, 662-3, 693-4, 725. New York, 1901.

LITHOGRAPHIC LIMESTONE.[7]

Lithographic stone must contain no grains or crystals, and must be of even texture.

Distribution.

The lithographic limestone of commerce is almost all from Solenhofen, Bavaria; it is of Upper Jurassic age.

Kentucky furnishes all the lithographic limestone produced in the United States.[8]

Lithographic limestone has been found in Alabama, Arizona, Arkansas, Illinois, Indiana, Iowa, Missouri, Tennessee, Texas, Utah and Virginia. It has not been found of commercial importance as yet in these states.

LIME.[9]

The importance of lime.

Lime (CaO) is made by driving off the carbonic acid (CO_2) from limestones ($Ca\,CO_3$).

Uses.

In making mortar, plaster and cements, and for whitewashing.

As a fertilizer.

Value of lime as a fertilizer; its effect upon soil.[10]

As a disinfectant.

Uses in chemistry and for manufacturing calcium carbide to make acetylene gas.

There are two kinds of lime: common lime, and hydraulic lime.

Characteristics of lime.

Slaking.

Rehardening or setting with foreign substances.

Sand in mortar furnishes points on which the lime crystallizes in setting.

Importance of lime in engineering and architectural works.

Occurrence.

Limestone available for the manufacture of lime is widely distributed. Lime products are usually manufactured near the limestone deposits.

[7]S. J. Kubel.—The production and consumption of lithographic stone. Engineering

[8]E. O. Ulrich.—The lithographic stone deposits of eastern Kentucky. Engineering and Mining Journal, LXXIII, 895-6. New York, 1902.

[9]E. C. Eckel.—Cements, limes, and plasters. New York, 1905.

[10]W. B. Elliott.—Lime in Virginia soils. Bul. 176 of Virginia Agr. Exp. Sta. Mar., 1910.

HYDRAULIC LIMESTONE.[11]

Hydraulic limestone contains clay and furnishes a lime that will set under water.

The hydraulic limestones of the United States are usually shaly and contain considerable magnesia.

Used for making hydraulic lime and cement.

ANALYSES OF HYDRAULIC LIMESTONES.

	Rosendale, N. Y.[12]	New York.	Wisconsin.
Lime carbonate	44.34	45.54	48.29
Magnesia carbonate	23.92	25.94	29.19
Silica	22.14	15.37	17.56
Alumina	3.80	9.13	1.40
Iron oxide		2.25	2.24
Water and organic matter	.83	1.20	

Distribution.

Geologic.

Most of the hydraulic limestone of the United States occurs in Paleozoic rocks.

Geographic.

Hydraulic limestone is by no means so widespread as ordinary limestone. The principal states in which it occurs and is utilized are NewYork, Indiana,[13] and Kentucky, Pennsylvania, Wisconsin, Illinois, and Iowa.[14]

Hydraulic Cement.

Hydraulic cement is made from hydraulic limestone; it sets under water.

Composition.

How made.[15]

Uses and importance.[16]

[11]Q. A. Gillmore.—On limes, hydraulic cements, and mortars. Ninth edition. New York, 1888.

[12]Cement mineral industry for 1894, III, 89-96. New York, 1895.

[13]C. E. Siebenthal.—The Silver Creek hydraulic limestone of southeastern Indiana. 25th ann. rep. Dept. of Geol. and Nat. Resources. Indiana Geological Survey. 331-389. Indianapolis, 1901.

[14]E. C. Eckel and H. F. Bain.—Cement and cement materials of Iowa. Geological Survey of Iowa, XV, 33-124. Des Moines, 1905.

[15]The manufacture of Rosendale cement. Engineering and Mining Journal, LXIV, 459. New York, 1897.

[16]S. B. Newberry.—On the theory of hardening of cements. Jour. Soc. Chem. Industry, 889. 1897.

Frank H. Eno.—The uses of hydraulic cement. Geol. Sur., Ohio., 4th ser., Bul. 2. Columbus, 1904.

A. V. Bleininger.—The manufacture of hydraulic cements. Bul. 3, Geol. Survey of Ohio. Columbus, 1904.

The principal manufacturing district is Rosendale, Ulster county, New York. The industry was established in 1823. The output of the Rosendale district in 1898 was 3,245,225 barrels, worth $2,103,554.

The district next in importance is that of Kentucky and Indiana, in the vicinity of Louisville. Its output in 1898 was 1,929,018 barrels, worth $482,254.

North Dakota also manufactures cement.[17]

[17]V. J. Melsted.—The manufacture of natural hydraulic cement. 5th Biennial rep. State Geological Survey, North Dakota, 212-225. Bismarck, 1908.

CHALK[18] AND MARLS.[19]

Chalk is an earthy, white limestone, for the most part composed of the skeletons of minute organisms.

Mode of formation.

Marl or bog lime.[19]

Uses.

For making whiting.

For crayons.

In the manufacture of Portland cement.[20]

In fertilizing.

Distribution.

Geographic.

England and France are the principal producers of chalk.

Deposits of chalk are found in the United States in Arkansas, Texas, Iowa, and Nebraska.

[18]J. C. Branner.—The cement-materials of southwest Arkansas. Trans. Amer. Inst. Min. Engs., XXVII, 42-63. New York, 1898.

J. A. Taff.—Chalk of southwestern Arkansas. 22nd ann. rep. U. S. Geological Survey, pt. III, 687-742. Washington, 1902.

Samuel Calvin.—The Niobrara chalk. American Geologist, XIV, 140-161. Minneapolis, 1894.

[19]D. J. Hale.—Marl and its application to the manufacture of Portland cement. Geological Survey of Michigan, VIII, pt. III. Lansing, 1900.

H. S. Sprackman.—Manufacture of cement from marl and clay. Proc. Eng. Club of Philadelphia, XX, 154-176. Philadelphia, 1903.

[20]D. B. Butler. Portland cement; its manufacture, testing, and use. London and New York, 1899.

Henry Reid.—The science and art of the manufacture of Portland cement, with observations on some of its constructive applications. New York, 1877.

J. C. Branner.—On the manufacture of Portland cement. Geol. Survey of Arkansas for 1888, II, 291-302.

C. D. Jameson.—Portland cement. A monograph. Iowa City, 1895.

S. B. Newberry.—Portland cement. Seventeenth ann. rep. U. S. Geological Survey, pt. III, 881-893. Washington, 1896.

U. Cummings.—American cements. Boston, 1898.

PORTLAND CEMENT is a hydraulic cement, made from carbonate of lime (3.29 parts) and clay (1 part). "Not over thirty or forty per cent of ordinary Portland cement which is active in the hardening process. The rest is inert and like so much sand."[21]

Methods of manufacture.[22]

Sixty per cent of silica required in the clay, magnesia limit from 3 per cent to 5 per cent. Magnesia tends to crumble the cement.

The cement yield is about 60 per cent of the weight of the chalk and clay.

USES OF PORTLAND CEMENT.

In mortar, for cementing building stones, for paving purposes, and in making artificial stone for building purposes.

Advantages of Portland cement.

Blocks may be made of any size or shape.

It hardens under water.

It is stronger and harder than any other cement.

Good coment gets stronger with age.

GYPSUM.[23]

Gypsum ($CaSO_4+H_2O$), sulphur trioxide 46.6, lime 32.5, water 20.9, is a soft hydrous sulphate of calcium, varying in color—white, red, yellow, brown, blue, black.

Uses.

In manufacture of "plaster of Paris[24] and cement plasters.[25]

[21]J. B. Johnson.—Proc. Amer. Assoc. for Adv. of Sci., XLVII, 244. Salem, 1898.

[22]Robert W. Lesley.—History of the Portland cement industry in the United States. Jour. Franklin Inst., CXLVI, 324-348. Philadelphia, 1898.

E. C. Eckel.—The materials and manufacture of Portland cement. Bul. 8, Geological Survey of Alabama. Montgomery, 1904.

R. L. Humphrey and Wm. Jordan, Jr.—Portland cement mortars and their constituent materials. Bul. 331, U. S. Geological Survey. Washington, 1908.

S. B. Newberry.—Portland cement. Twentieth ann. rep. U. S. Geological Survey, pt. VI continued, 539-546. Washington, 1899.

G. P. Grimsley.—The Portland cement industry in California. Engineering and Mining Journal, LXXII, 71-72. New York, 1901.

[23]Robert Hay.—Geology and mineral resources of Kansas, 46-48. Topeka, 1893.

Lewis C. Beck.—Mineralogy of New York, 61-67. Albany, 1842.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Mus. for 1899, 406-411. Washington, 1901.

F. A. Wilder.—The present and future of the American gypsum industry. Engineering and Mining Journal, LXXIV, 276-278. New York, 1902.

[24]P. Wilkinson.—The technology of cement plaster in Kansas. Engineering and Mining Journal, LXVI, 576. New York, 1898.

[25]G. P. Grimsley and E. H. S. Bailey.—Special report on gypsum and gypsum cement plasters. Univ. Geol. Survey of Kansas, V. Topeka, 1899.

As a fertilizer, commonly called "land plaster."
For delicate statuary (alabaster).
In China it is used as a cosmetic, as medicine, and as an adulterant in flour.
Varieties.
Selenite.
Fibrous gypsum or satin spar.
Alabaster.

Modes of Occurrence.

Usually dull colored on account of impurities; in beds often of great thickness, interstratified with limestones, clays, and salt.

Origin.

Usually deposited from salty solutions in partly enclosed seas.

Distribution.

Gypsum is widespread, geographically as well as geologically.
Its distribution in the United States is fairly well shown by the following statistics.[26]

VALUE OF GYPSUM PRODUCED IN THE UNITED STATES IN 1908.

Alaska, Colorado, New Mexico, South Dakota, and Utah	$402,806
California, Nevada, and Oregon	294,046
Iowa	730,383
Kansas	414,266
Michigan	681,351
New York	800,225
Ohio and Virginia	669,537
Oklahoma and Texas	824,617
Wyoming	125,033

[26]G. I. Adams.—Gypsum deposits in the U. S. Bul. 223, U. S. Geological Survey. Washington, 1904.

E. F. Burchard.—Gypsum. Min. Res. U. S. for 1908, pt. II, 621-628. Bibliography. Washington, 1909.

F. J. H. Merrill.—Salt and gypsum industries of New York. Bul. New York State Museum, III, no. 11. Albany, 1893.

W. P. Blake.—Gypsum beds in southern Arizona. Amer. Geologist, XVIII, 394. Minneapolis, 1896.

G. P. Grimsley.—The origin and age of the gypsum deposits in Kansas. American Geologist, XVIII, 236-237. Minneapolis, 1896.

G. P. Grimsley.—Gypsum in Kansas. Kansas Univ. Quarterly, VI, 15-27. 1897.

C. R. Keyes.—Iowa gypsum. Mineral Industry, IV, 379-388. New York, 1896.

Bibliography of gypsum in the U. S. Min. Res. U. S. for 1906, 1077-1078. Washington, 1907.

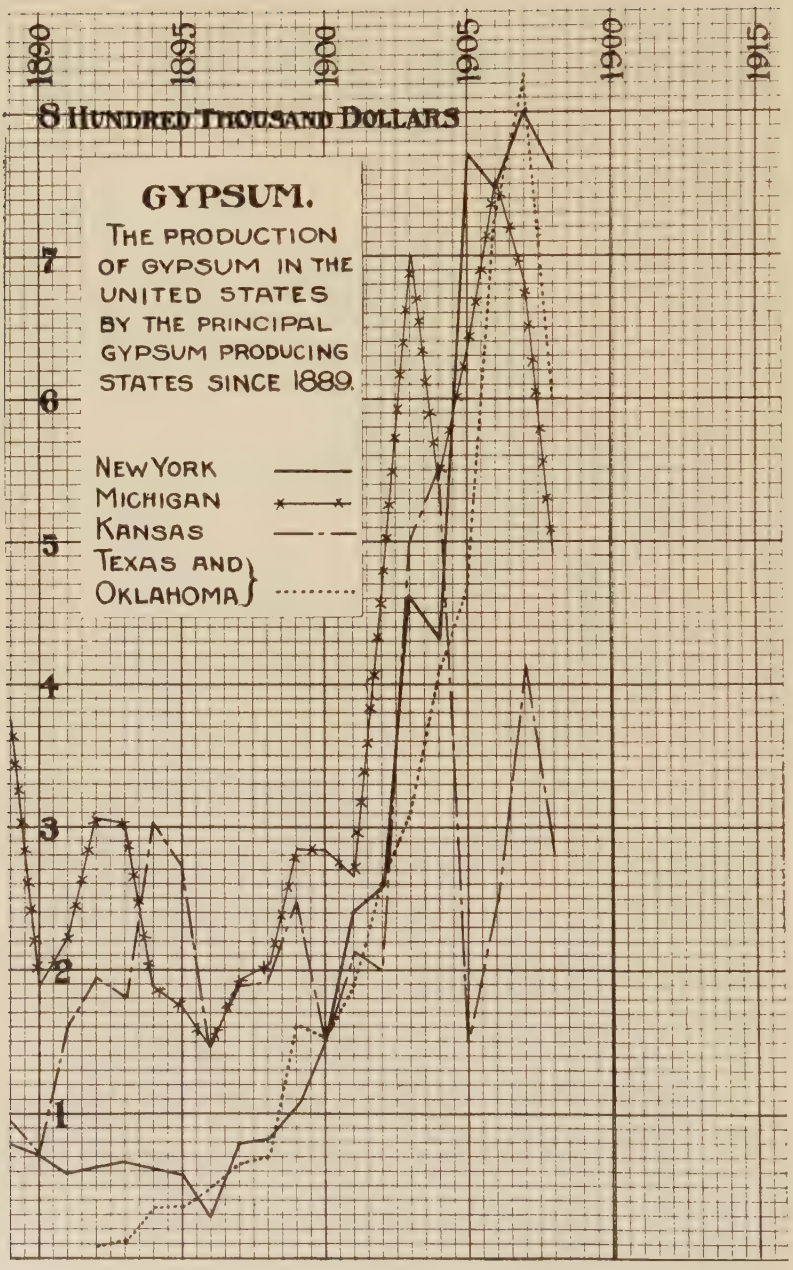
1890
1895
1900
1905
1910
1915
8 HUNDRED THOUSAND DOLLARS
GYPSUM.
THE PRODUCTION OF GYPSUM IN THE UNITED STATES BY THE PRINCIPAL GYPSUM PRODUCING STATES SINCE 1889.
NEW YORK
MICHIGAN
KANSAS
TEXAS AND OKLAHOMA
7
6
5
4
3
2
1

Fig. 110.

KAOLIN.[1]

Kaolin is mostly kaolinite ($2H_2O.Al_2O_3.2SiO_2$), a hydrous silicate of alumina, containing silica 46.5, alumina 39.5, water 14.0. Kaolin always contains other substances as impurities. Varieties of kaolin with water varying from 7.50 per cent in rectorite to 28.8 per cent in newtonite.

Uses.

The finest grades of kaolin are used for making fine poreclain and chinaware.

Kaolin from near St. Yrieix, France, used for the Limoges and Sèvres porcelain.

The common grades are used for cream-colored ware, sanitary ware, and other ordinary grades of pottery, and for decorative tiles.

Origin.

Kaolin is formed by decomposition from aluminous minerals, especially from the feldspars.

Composition of feldspar.

Changes necessary to produce kaolin.

Experiments of Daubrée on pulverized feldspar.

Occurrence.

1. In irregular beds in decayed granites, porphyries, and gneisses.

Quarries near St. Yrieix, France.

Formerly mined at Brandywine Summit, Pa.[2]

Quarrying and mining methods in irregular deposits.

Original deposits to be sought only in rocks whose decay would furnish kaolin.

2. In regular sedimentary beds by removal of original deposits, and deposition in water.

Examples of Arkansas kaolins.

Conditions under which sedimentary kaolins may be formed.

Determination of sedimentary kaolin.

[1] T. C. Hopkins.—Kaolin; its occurrence, technology, and trade. Mineral Industry for 1898, VII, 148-160. New York and London, 1899.

A. Brongiart.—Traité des arts céramiques. Paris, 1854.

Bruno Kerl.—Handbuch der gesammten Thonwaarnindustrie. Braunschweig, 1879.

J. C. Branner.—A bibliography of clays and the ceramic arts. American Ceramic Society. Columbus, O., 1906.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Museum for 1899, 325-353. Bibliography. Washington, 1901.

[2] J. P. Lesley.—(On Pennsylvania kaolin deposits.) Ann. rep. Geological Survey of Pennsylvania for 1885, 571-614. Harrisburg, 1886.

Kaolin may occur in rocks of any geologic age, and in any part of the world containing the feldspathic rocks capable of forming it upon decay or alteration.

Treatment.

Practically no kaolin is now used as it comes from the ground.
Hand picking; grinding; settling; addition of "flint" or quartz and feldspar.
Effect of drying on different kaolins.
Effect of burning.
Loss of plasticity; change of color and composition.

CLAY.[3]

Clay is for the most part an impure kaolin, formed originally in the same way.
Examples of differences shown by analyses.
Clays of organic origin.

Uses.[4]

Manufacture of common bricks, "vitrified" bricks for paving, tiles for drains and roofing, terra cotta for ornamental and architectural purposes, common pottery, door knobs, chimney pots, sewer pipes, and playing marbles.
Refractory purposes.

Occurrence.

Residuary clays from the decomposition of rocks in place.
Forms of deposits from decay along the outcrops of sedimentary rocks.
Forms of deposit from the decay of crystalline rocks.
Transported clays.
Forms of the beds.
Cause of areal changes in the characters of the beds.
Why some beds are thick and others thin.
Why some beds are hard and others soft.

[3]R. T. Hill.—Clay materials of the United States. Mineral Resources of the U. S. for 1891, 474-528. Washington, 1893.
H. Ries.—Clays: Their occurrence, properties and uses with especial reference to those of the U. S. New York, 1906.

[4]Annual reports of the National Brick Manufacturers' Association. Indianapolis, since 1887.
The Clay Worker (Monthly). Indianapolis, 1884.
C. T. Davis.—A practical treatise on the manufacture of bricks, tiles, terra-cotta, etc. Philadelphia, 1889.
J. Middleton.—Clay products. 12th Census of the U. S. IX, pt. III, 901-945. Washington, 1902.

The loess clays of the Mississippi valley.
The Milwaukee brick clays.
Why the bricks are cream colored.[5]
Formation of slates, and clays derived from them.

Distribution.

Clays are found among the sedimentary rocks of all ages and in all countries.
The clay industries of the United States.
New Jersey:[6] Trenton potteries.
Ohio: East Liverpool and Cincinnati potteries.
Missouri: St. Louis brick industries.
Georgia.[7]
The value of the clay products of the United States from 1889 until 1898 was between nine and ten millions of dollars annually; and in 1907 nearly $159,000,000 of clay products were produced.

[5]E. R. Buckley.—The clays and clay industries of Wisconsin, 60-63. Madison, 1901.
[6]G. H. Cook and J. C. Smock.—Report on the clay deposits of New Jersey. Trenton, 1878.
[7]O. Veatch.—Clay deposits of Georgia. Bul. 18, Geological Survey of Georgia. Atlanta, 1909.

FULLERS' EARTH.[1]

Fullers' earth is a clay in an extremely finely divided state. It is greenish gray, olive and brown in color, and feels greasy when rubbed between the fingers.

Uses.

It was first used by fullers to take grease out of cloth, hence the name.
Cleaning furs.
Clarifying cotton seed oil and petroleum.
The great demand for fullers' earth for heating oil in the United States keeps the price of it very high.

Occurrence.

Geologic.
It occurs as bedded deposits in sedimentary rocks of any geologic age.
Geographic.
England.
Deposits occur in the Jurassic and Cretaceous beds at Nutfield, Surrey.

Fullers' Earth in the United States.

Florida.
The deposit is a bed 8 to 10 feet thick of Miocene age.
South Carolina has beds of fullers' earth in the Eocene.
Georgia and South Dakota also furnish fullers' earth of Tertiary age.
Arkansas.
The fullers' earths in Arkansas are the weathered portions of Tertiary clay beds. They cover large areas in the eastern and southern parts of the state.

[1]John T. Porter.—Properties and tests of fullers' earth. Bul. 315, U. S. Geological Survey, 268-290. Washington, 1907.
T. W. Vaughan.—Fuller's earth deposits of Georgia and Florida. Bul. 213, U. S. Geological Survey, 392-399. Washington, 1903.
D. T. Day.—The occurrence of fullers' earth in the United States. Journal of the Franklin Institute, CL, 214-223. Philadelphia, 1900.
For short list of papers on fullers' earth see Bul. 380, U. S. Geological Survey, 358-360. Washington, 1909.

GLASS-SAND.[1]

The essential constituent for manufacturing glass is silica; it is found as loose sand or as more or less compact sandstone.

Purity of sand, especially freedom from iron or other coloring matter, is necessary.

ANALYSES OF GLASS-SAND.

Constituents.	Isle of Wight.	France.
Silica	97.0	98.8
Moisture	1.0	0.5
Oxide of iron and magnesium	2.0	0.7
	100.0	100.0

Distribution.

Sand that may be used for making glass has a very wide distribution. England, France, Germany, Austria, Belgium, Holland, Sweden, Canada and Brazil are all rich in glass-sands. It may occur in rocks of any geologic age.

Glass-Sand in the United States.

New Jersey[2] has extensive deposits of Tertiary age.

Pennsylvania[3] from the Oriskany sandstone in Mifflin county.

West Virginia[4] from the Oriskany sandstone in Morgan county.

Indiana[5] in Madison, Parke, Clark, and Harrison counties.

Michigan glass-sands are from the shores of Lake Michigan.

Wisconsin:[6] glass made from the St. Peter's and the Potsdam sandstone.

[1]J. D. Weeks.—Tenth Census. II, 1029-1152. Washington, 1883.
J. D. Weeks.—Glass materials. Mineral Resources of the U. S. for 1885, 544-555. Washington, 1886.
S. P. Austin.—Glass. 12th Census, U. S., IX, pt. III, 949-1000. Washington, 1902.

[2]G. H. Cook.—Geology of New Jersey, 1868, 690-695, and 293. Newark, 1868.

[3]Second Geological Survey of Pennsylvania, 1888-89. Rep. F3, 271-274, 288-292. Harrisburg, 1891.

[4]G. W. Stose.—The glass and industry in eastern West Virginia. Bul. 285, U. S. Geological Survey, 473-475. Washington, 1906.

[5]John Collett.—Glass-sand. Geology and natural history of Indiana. Twelfth ann. rep. 22, 1882. Indianapolis, 1883.
E. F. Burchard.—Glass-sand industry of Indiana, Kentucky, and Ohio. Bul. 315, U. S. Geological Survey, 361-382. Washington, 1907.

[6]Geology of Wisconsin, 1873-77, II, 290, 546, 558. 1877.

Missouri[7] at Crystal Springs in Jefferson county.

Iowa[8] has glass-sands in the St. Peter's sandstone of the Lower Silurian.

Kentucky.[5]

Ohio.[5]

[7]Geological Survey of Missouri, 1855-1871, 62, 129, 200, 273, 289, 302. Jefferson City, 1873.

Geological Survey of Missouri, 1872, 289. New York, 1873.

E. F. Burchard.—Glass-sands of the Middle Mississippi basin. Bul. 285, U. S. Geological Survey, 459-472. Washington, 1906.

[8]C. R. Keyes.—Saint Peter sandstone. Iowa Geological Survey. First ann. rep. for 1892, I, 24-25. Des Moines, 1893.

FELDSPAR.[1]

COMPOSITION OF THREE KINDS OF FELDSPAR.

	Orthoclase.	Albite.	Anorthite.
Silica	64.7	68.7	43.2
Alumina	18.4	19.5	36.7
Potash	16.9	Soda 11.8	Lime 20.1

Orthoclase ($KAlSi_3O_8$) is the feldspar of commerce.

Uses.

Manufacture of pottery and tiles; used as a flux, and for glazing. The gem "moonstone."

Occurrence.

Feldspar is one of the constituent minerals of granites, gneisses, and syenites. It sometimes occurs in segregations in these rocks.

Most of the feldspar of the United States comes from Connecticut, New York, and Pennsylvania.[2]

The production of feldspar in the United States in 1908 was 67,240 tons, worth $400,918.

[1] T. C. Hopkins.—Feldspar: its occurrence, mining and uses. The Mineral Industry for 1898, VII, 262-268. New York, 1899.

H. Ries.—Flint and feldspar. Mineral Resources of the United States for 1901, 935-939. United States Geological Survey. Washington, 1902.

E. S. Bastin.—Economic geology of the feldspar deposits of the United States. Bul. 420, U. S. Geological Survey. Washington, 1910.

[2] T. C. Hopkins.—Clays and feldspars of southern Pennsylvania. Mining Bulletin, IV, 106-107. Sept., 1898.

MINERAL PIGMENTS.[1]

Many pigments are minerals, either natural or artificial products.

The more important minerals used as pigments are here brought together for convenience of reference.

Antimony is a constituent of antimony yellow, Naples yellow, and antimony red.

Arsenic is extensively used as a pigment, especially for green colors. It is a component of Paris green, Scheele's green, orpiment (King's yellow), realgar, Schweinfurth blue.

Barium is a constituent of manganese green, certain yellow colors, and "constant white."

Cadmium is used in making various yellows.

Calcium is a constituent of Venetian red, and is used in Spanish white and Paris white.

Gypsum (calcium sulphate) is used in making "terra alba."

Chromium is an important pigment as a green and yellow. It is a constituent of chrome yellow (lead chromate), "perfect yellow" (zinc chromate), chrome green, Guinet's green, Mittler's green, Veronese green.

Cobalt is used in making yellow, blue, and green pigments; cobalt yellow, cobalt green, Gellert's green, cobalt blue, cerulean blue, Leitch's blue.

Copper is extensively used in making greens and blues. It is a constituent of Bremen green, Brunswick green, Casselmann's green, Elsner's green, Paris green, Gentele's green, "mineral greens," Scheele's green, Alexandria blue, Bremen blue, and Schweinfurth blue.

Graphite paint is used for metal exposed to the weather.

[1]H. H. Harrington and P. S. Tilson.—Paints and painting material. Bul. 44, Texas Agr. Exp. Sta. Austin, 1898.

Spons' encyclopedia of arts and manufactures, II, 1548-1556. London, 1882.

Blount and Bloxam.—The chemistry of manufacturing processes, XV, 449-467. Philadelphia, 1897.

Thomas B. Stillman.—Paint analysis. The digest of physical tests, 1897, II, 114-127. (Bibliography.)

E. W. Parker.—Mineral paints. Sixteenth ann. rep. U. S. Geological Survey, 1894. 1895, pt. IV, 694-702. Washington, 1895.

Robert Hay.—Trans. Kansas Acad. Sci., 1893-94, XIV, 243. Topeka, 1896.

E. W. Parker.—Mineral paints. Twentieth ann. rep. U. S. Geological Survey, pt. VI (continued), 719-737. Washington, 1899.

E. J. Parry and J. H. Coste.—The chemistry of pigments. London, 1902.

Iron[2] is a constituent of the ochres, of Prussian green, Alexandria blue, Antwerp blue, Chinese blue, Leitch's blue, Prussian blue, Indian red, Venetian red, sienna, and umber.

Lead[3] is a constituent of chrome yellow, Naples yellow, and red lead. White lead is lead carbonate or sulphate.

Magnesium is used in making Indian yellow.

Manganese is a constituent of manganese green, sienna, and umber.

Potassium is a constituent of cobalt yellow, Casselmann's green, Schweinfurth blue.

Tin is a constituent of cerulean blue.

Ultramarine is a combination of silica, alumina, sulphuric acid, soda, iron, sulphur, and magnesia.

Vanadium[4] is used in the preparation of analine black, for coloring porcelain, and in metallurgy.

Whiting is pure chalk.

Zinc is used in "perfect yellow," cobalt green, Gellert's green, methyl green, and zinc white.

[2]Ochre and oxide of iron pigments. The mineral industry, VII, 532-536. New York, 1899.

F. A. Hill.—Report on metallic paint ores along the Lehigh River. Geological Survey of Pennsylvania for 1886, pt. IV, 1386-1408. Harrisburg, 1887.

C. E. Hesse.—The paint-ore mines of the Lehigh gap. Trans. Amer. Inst. Min. Eng., XIX, 321-330. New York, 1891.

[3]G. W. Thompson.—Relative values of lead and zinc. Engineering and Mining Journal, LXXVI, 398-399. New York, 1903.

G. S. Fraps.—Composition of white lead and paints. Bul. 14, Texas Agr. Exp. Sta. Austin, 1908.

[4]G. J. Rockwell.—Index to literature of vanadium, 1801-1877. Annals New York Academy of Sciences, I, 133-143. New York, 1879.

J. Kent Smith.—The present source and uses of vanadium. Trans. Amer. Inst. Min. Eng., XXXVIII, 698-703. New York, 1908.

D. Foster Hewett.—Vanadium-deposits of Peru. Bul. 27, Amer. Inst. Min. Eng., 291-316. New York, 1909; XL, 274-299. New York, 1910.

Discussion by J. F. Kemp. ibid. XL, 861-863. New York, 1910.

W. F. Hillebrand and F. L. Ransome.—On carnotite and associated vanadiferous minerals in western Colorado. Bul. 262, U. S. Geological Survey, 9-31. Washington, 1905.

ASPHALT.[1]

Varieties of asphalt are known also as grahamite, gilsonite, uintaite, albertite, wurtzilite, elaterite, etc. It is from brown to black in color, brittle to a blow, and melts at 200° F. and lower.

Uses.

Its principal use is street paving.

In architecture; lining reservoirs; foundations for heavy machinery; coating for pipes, piles, fence posts, paving blocks, wire poles; as an insulator.

It is also used in different mixtures as a waterproof material for metals, papers, fabrics, and roofing.

Origin.[2]

Asphalt or asphaltum is a residue or base resulting from distillation of petroleum or other organic accumulations.

Evidences to support this theory.[3]

Occurrence.[4]

It occurs in beds and veins mixed with more or less earthy matter or impregnating limestone or sandstone.

The most important asphalt deposit known is on the island of Trinidad off the coast of Venezuela, where it occurs at the surface like a lake and covers an area of 116 acres.[5] This deposit is remarkable for its purity.

[1]W. C. Day.—The production of an asphalt resembling gilsonite by the distillation of a mixture of fish and wood. Proc. Amer. Phil. Soc., XXXVII, 171-174. Philadelphia, 1898.

W. C. Day.—The laboratory production of asphalts from animal and vegetable materials. Jour. Franklin Inst., CXLVIII, 205-226. Philadelphia, 1899.

I. C. White.—Origin of grahamite. Bul. Geol. Soc. Amer., X, 277-284. Rochester, 1899.

H. Wurtz.—A theory of asphalto-genesis.—Engineering and Mining Journal, XLVIII, 73-74. New York, 1889.

F. V. Greene.—Asphalt and its uses. Trans. Amer. Inst. Min. Eng., XVII, 355-375. New York, 1889.

E. W. Parker.—Asphaltum and bituminous rock. Twentieth ann. rep. U. S. Geological Survey, pt. VI (continued), 251-268. Washington, 1899.

[2]S. F. Peckham.—The genesis of bitumens, as related to chemical geology. Proc. Amer. Phil. Soc., XXXVII, 108-139. Philadelphia, 1898.

[3]W. C. Morgan and M. C. Tallmon.—A fossil egg from Arizona. University of California publications, Bul. Dept. Geol., III, no. 19, 403-410. Berkeley, 1904.

[4]G. H. Eldridge.—The formation of asphalt veins. Economic Geology, I, 437-444. 1906.

[5]S. F. Peckham and Laura A. Linton.—On Trinidad pitch. Amer. Jour. Sci., CLI, 193-207. New Haven, 1896.

Minor deposits of asphalt also occur in the islands of Barbados,[6] and Cuba.[7]

Deposits in the United States.[8]

California.[9]

The most important asphalt deposits in the United States are in the Tertiary rocks of California.

In Kern county it occurs in veins and superficial beds.

In Santa Cruz county bituminous beds are quarried about seven miles northwest of the city of Santa Cruz.

In San Luis Obispo county asphalt occurs in superficial deposits from oil springs.

In Santa Barbara county liquid asphalt and asphalt mixed with sand and other substances are found in veins and beds and in sandstones and shales.

Fig. 111.—Section near La Brea creek, Santa Barbara county, California, showing the geological structure and the accumulation of bitumen. (Cooper.)

In Ventura county it occurs in irregular veins, and impregnating sandstone.

The output of California increased from $598,502 worth in 1897, to $1,347,257 in 1908.

[6]W. Merrivale.—Barbadoes manjak. Engineering and Mining Journal, LXVI, 790-791. New York, 1898.

[7]H. E. Peckham.—On the bituminous deposits situated at the south and east of Cardenas, Cuba. Amer. Jour. Sci., CLXII, 33-41. New Haven, 1901.

[8]G. H. Eldridge.—The asphalt and bituminous rock deposits of the United States. Twenty-second ann. rep. U. S. Geological Survey, pt. I, 209-452. Washington, 1901.

[9]W. L. Watts.—The gas and petroleum yielding formations of the central valley of California. California State Mining Bureau, Bul. no. 3. Sacramento, 1894.

A. S. Cooper.—The genesis of petroleum and asphaltum in California. California Mines and Minerals, 114-174. San Francisco, 1899. Same in Bul. 16, California State Mining Bureau. Sacramento, 1899.

S. F. Peckham.—The technology of California bitumens. Jour. Franklin Inst., CXLVI, 45-54. Philadelphia, 1898.

Other states.

The only other states that have produced asphalt in commercial quantities are Kentucky,[10] Texas, [11] Oklahoma, [12] Colorado,[13] and Utah.[14]

In Utah it is known as *gilsonite* or *uintaite.*

[10]W. E. Burk.—Asphalt rock in Kentucky. Engineering and Mining Journal, LXXV, 969-970. New York, 1903.

[11]Coal, lignite, and asphalt rocks. Bul. 3, Univ. Texas Min. Survey. Austin, 1902.

[12]W. R. Crane.—Asphalt in the Indian Territory. Engineering and Mining Journal, LXXX, 442-443. New York, 1905.

[13]J. S. Newberry.—Grahamite in Colorado. School of Mines Quarterly, VIII, 332-337. New York, 1887.

[14]G. H. Eldridge.—The uintaite deposits of Utah. Seventeenth ann. rep. U. S. Geological Survey, pt. I, 915-949. Washington, 1896.

Asphaltum mineral resources, 1893, 627-669. Washington, 1894.

W. P. Blake.—Uintaite, albertite, grahamite, and asphaltum. Trans. Amer. Inst. Min. Eng., XVIII, 563-582. New York, 1890.

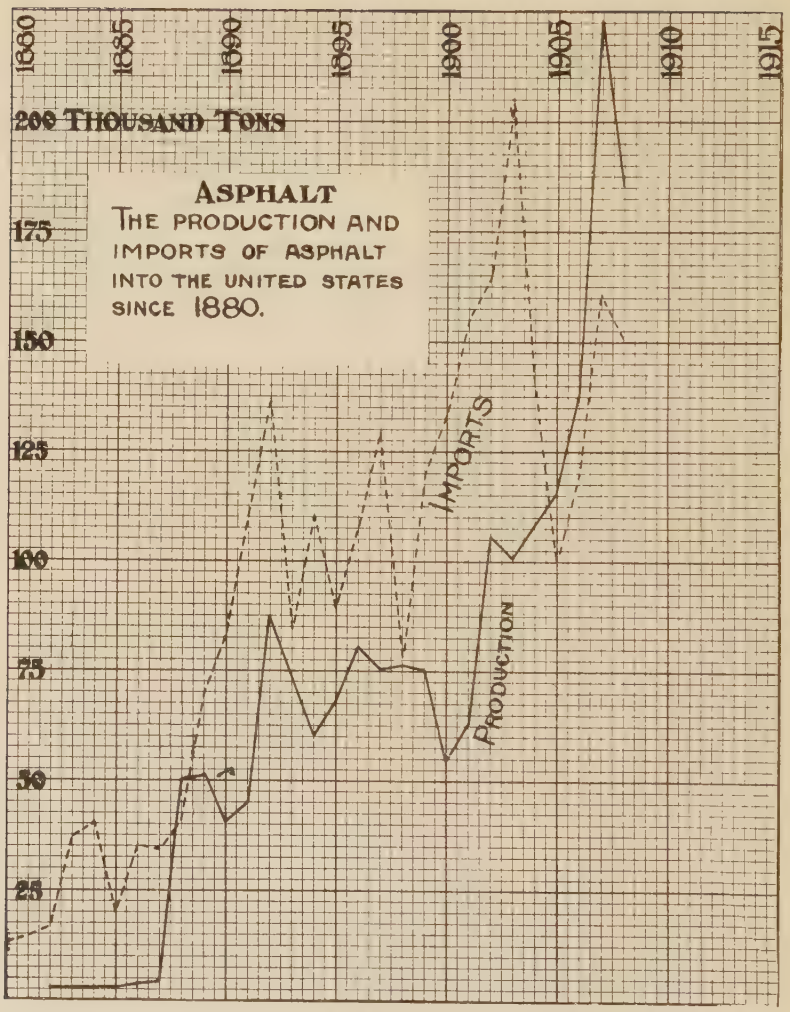
1880
1885
1890
1895
1900
1905
1910
1915
200 THOUSAND TONS
175
150
125
100
75
50
25
ASPHALT
THE PRODUCTION AND IMPORTS OF ASPHALT INTO THE UNITED STATES SINCE 1880.
IMPORTS
PRODUCTION

Fig. 112.

ROAD MATERIALS.[1]

Reference is here made only to road metal or top-dressing for common macadam or telford roads.

The essential qualities of good road metal are: that it pack hard and smooth; that it resist the wear of traffic and of weather; that it produce as little dust and mud as possible.

Importance of toughness as against hardness and brittleness.

INFERIOR MATERIALS.[2]

Materials that fail to meet the requirements mentioned above are more or less objectionable.

Feldspathic rocks on decay, or when powdered, form kaolin, a very sticky mud when wet and a fine dust when dry.

Syenite (80 per cent feldspar), granite, gneiss.

Clay shale composed of clay; when crushed makes mud or dust.

Limestone is too soft, for though much used, it is easily ground to mud or dust.

Clean sandstone has no binding and is too loose.

Clean hard pebbles from streams if without binding material do not pack readily.

SUPERIOR MATERIALS.

Gravels of hard rock with binding materials.

Paducah, Ky., gravels cemented by iron.

Sandy shales.

Mauch Chunk red shales of Pennsylvania with iron cement.

Chert gravel, natural or artificial, containing some lime or iron.

Good roads of the chert region of Missouri, Arkansas, and Tennessee.

[1] N. S. Shaler.—Geology of the road-building stones of Massachusetts, etc. Sixteenth ann. rep. U. S. Geological Survey, pt. II, 277-341. Washington, 1895.

E. Dietrich.—Die Baumaterialien der Steinstrassen. Berlin, 1885.

Bulletins of the Office of Road Inquiry. U. S. Dept. of Agriculture. Washington, D. C.

N. S. Shaler.—The common roads. Scribner's Magazine, VI, 473-483. October, 1889.

E. G. Love.—Pavements and roads: their construction and maintenance. New York, 1890.

F. J. H. Merrill.—Road materials and road building in New York. Bul. N. Y. State Museum, IV, no. 17. Albany, 1897.

J. O. Baker.—A treatise on roads and pavements. New York, 1903.

T. W. Smith.—Dustless roads. London, 1909.

W. H. Fulweiler.—The development of modern road surfaces. Jour. Franklin Inst., CLXVIII, 155-183. Philadelphia, 1909.

[2] N. S. Shaler.—Rocks suitable for road-making. Stone, XIII, 571-572. Chicago, 1896.

How the gravels accumulate in streams.
Necessity of screening them.
Influence of the lime in hardening.

Novaculite and jasper gravels.
Breaking up of novaculite by joints.
Accumulation in stream channels.
The jasper beds of California, Wisconsin, and North Carolina.

Hardening road metal.
Influence of iron, illustrated by the canga of Brazil, and the iron-bearing gravels of Paducah, Ky.; influence of lime.
Possibility of improving poor materials with iron.

Distribution of Materials.

Gravels in the glaciated areas.
Modern gravels in stream channels; dredged from the Ohio at Evansville.
Sandy shales with other sedimentary rocks.
Chert gravels of Lower Carboniferous and Silurian ages.
Novaculites of Arkansas follow structural features.
Where iron may be had for hardening.
Poor iron ores available.

REFRACTORY MATERIALS.[1]

Refractory materials are substances of various compositions, capable of withstanding high temperature without fusing.

Uses.

They are used for lining, furnaces, stoves, and chimney backs, and making crucibles, hearths, retorts, and the like used in metallurgical works. Clay of low refractoriness is used for making sewer pipes and "vitrified" paving bricks.

Composition.

(Some infusible substances are not mentioned here because they are not practically available.)

Refractory materials vary greatly in composition.

Aluminous: fire-clay, bauxite, kaolin, mica.

Magnesian: asbestos, magnesite, talc.

Carbonaceous: graphite.

Calcareous: pure lime.

Siliceous: pure quartz of Dinas bricks.[2]

Ganister: ground quartz and fire-clay used in lining Bessemer converters.

Chromium: chromite is used as refractory material.

The refractoriness of most substances depends upon their purity.

Pure lime highly refractory alone, but it is a flux with certain other substances.

Magnesia is refractory alone, but it is a flux in combination.

Pure silicia used for Dinas bricks lowers the refractoriness of certain other substances.

FIRE CLAY.[3]

Clays and kaolins are hydrous silicates of alumina. Fire-clays proper are simply clays that do not fuse readily.

Fire clays may occur with sedimentary rocks of any age.

[1]John Percy.—Metallurgy. Refractory materials: crucibles, furnaces, fire-bricks, etc., 87-154. London, 1875.

A. Humboldt Sexton.—Fuel and refractory materials. London, 1896.

R. L. Humphrey.—The fire-resisting properties of various building materials. Bul. 370, U. S. Geological Survey. Washington, 1909.

[2]W. A. Shenstone.—Vitrified quartz. Nature, LXIV, 65-67. London, 1901.

[3]H. O. Hofman and C. D. Demond.—Some experiments for determining the refractoriness of fire-clays. Trans. Amer. Inst. Min. Eng., XXIV, 42-66. New York, 1895.

Carl Bischof.—Die Feuerfesten Thone. Leipzig, 1876.

T. C. Hopkins.—A short discussion of the origin of the coal measures fire clays. American Geologist, XXVIII, 47-51. Minneapolis, 1901.

They have been deposited in ponds or marshes or in very quiet waters.

Why they are so abundant in the Carboniferous.

Their structural features are due to the conditions of deposition.

Varying degrees of refractoriness.

Refractoriness determined by composition and physical condition.

FLUXING INFLUENCE OF THE COMMON CONSTITUENTS OF CLAYS ON A SILICATE OF ALUMINA AS DETERMINED BY BISCHOF.

Equivalent parts by weight:

- 20 of magnesia.
- 28 of lime.
- 31 of soda.
- 40 of iron oxide.
- 47 of potash.

Bischof's empirical formula, based on chemical composition, is as follows:

$$\text{Refractoriness} = \frac{(Al_2O_3)^2}{M \times SiO_2} \times 0.2759$$

$$[M = (0.6 \times Fe_2O_3) + (0.857 \times CaO) + (1.2 \times MgO) + (0.5092 \times K_2O) + (0.7729 \times Na_2O).]$$

According to this formula fire-clay of Cheltenham, Mo., has refractoriness of 0.86; best Stourbridge clay, 1.28; clay for vitrified brick, 0.24 to 0.34.

Wherein analyses of clays may not be trusted.

The refractoriness of a single clay *varies with physical condition.*

Use of "grog," or "chamotte" to reduce the shrinkage.

The refractoriness of aluminous clays may be greatly increased by the use of bauxite.

Paving-bricks are made of fire-clay of low refractoriness.

How to increase or decrease refractoriness.

MAGNESITE.[4]

(Carbonate of magnesia ($MgCO_3$): magnesia 47.6; carbon dioxide 52.4.

Uses.

Used as linings in basic hearths of steel furnaces and for fireproofing buildings.

[4]Henry G. Hanks.—A history of magnesia, and its base and compounds. San Francisco, 1895.

Magnesite in India. Engineering and Mining Journal, LXVI, 669-670. New York, 1898.

S. J. Vlasto.—The magnesite industry. Engineering and Mining Journal, LXIX, 288-9. New York, 1900.

It is also used for:

Bleaching agent and filler in making wood-pulp paper.
Manufacture of magnesium salts.
Manufacture of carbonic acid for artificial mineral waters.
Manufacture of metallic magnesium.

Occurrence and Distribution.

Associated with serpentines, talcose schists, and other magnesian rocks, in thin veins and stringers.

Mined near Veitsch, Austria, and made into fire-brick.

At Bolton, Canada,[5] the deposit is said to be 60′ thick.

In Silesia, Germany, there are deposits at Grochau and Baumgarten.

In Greece[6] it forms veins in serpentines.

In the United States it is associated with serpentine beds on Staten Island in New York. In California it is found in Fresno, Alameda, Napa, Santa Clara, San Mateo, and other counties. It can probably be found as white veins in serpentine wherever the latter occurs. It is worked in California.[7]

The California output in 1906 was 7,805 tons, worth $23,415; in 1908, 6,587 tons, worth $19,761.

CHRYSOTILE (ASBESTOS).[8]

Commercial "asbestos" is chrysotile ($H_4Mg_3Si_2O_9$), a fibrous variety of serpentine: silica 44.1, magnesia 43.0, water 12.9; another kind is a fibrous variety of amphibole.

Uses.

It is used for steam packing; covering for boilers, steam pipes, and hot-water pipes; fireproofing for buildings and safes; lining for gas stoves and fireplaces; for the manufacture of fireproof cloths and theatre curtains; and for weighting silks.

[5]G. C. Hoffman.—Magnesite. Ann. rep. Geological Survey of Canada, XIII, R, for 1900, 14-19. Ottawa, 1903.

[6]F. Meijnan.—The magnesite industry of Greece. Engineering and Mining Journal, LXXXVI, 962. New York, 1908.

F. Meijnan.—Grecian magnesite. Eng. and Min. Jour., LXXXVI, 730. New York, 1908.

[7]F. L. Hess.—The magnesite deposits of California. Bul. 355, U. S. Geological Survey. Washington, 1908.

[8]R. W. Ells.—The mining industries of eastern Quebec. Trans. Amer. Inst. Min. Eng., XVIII, 320-328. New York, 1890.

G. P. Merrill.—Notes on asbestos and asbestiform minerals. Proc. U. S. National Museum, 1895, XVIII, 281-292. Washington, 1896.

R. H. Jones.—Asbestos and asbestic; their properties and occurrence. London, 1897.

Occurrence and Distribution.

It occurs in narrow veins in serpentine rocks;[9] the veins but few inches wide; the fibers cross the veins.

Nearly all the asbestos used in the United States comes from Quebec,[10] Canada, which produces 58% of the world's supply.

ASBESTOS IN THE UNITED STATES.[11]

Asbestos occurs at and about Sall Mountain in Georgia as a fiberized variety of amphibolite. This is the principal deposit in the United States. Minor deposits occur in Virginia, Vermont, Texas, Wyoming,[12] Arizona, and California.

Asbestos in the Philippines.[13]

VALUES OF THE ASBESTOS PRODUCED AND IMPORTED INTO THE UNITED STATES.

	Produced	Imported
1880	?	$ 9,736
1890	$ 4,560	257,899
1895	13,525	244,878
1900	16,310	355,951
1904	25,740	751,862
1907	11,899	1,316,379
1908	19,624	1,195,870

[9]G. P. Merrill.—On the origin of veins in asbestiform serpentine. Bul. Geol. Soc. Amer., XVI, 131-136. Rochester, 1905.

[10]J. A. Dresser.—On the asbestos deposits of the eastern townships of Quebec. Economic Geology, IV, 130-140. March, 1909.

[11]J. S. Diller.—Asbestos. Mineral Resources for 1907, pt. II, 711-722. Washington, 1908.

[12]H. C. Beeler.—Asbestos in Wyoming. Engineering and Mining Journal, XC, 955. New York, 1910.

[13]W. D. Smith.—The asbestos and manganese deposits of Ilocos Norte (P. I.). Phil. Jour. Sci., II, 145-177. Manila, 1907.

TALC.[14]

Talc ($H_2Mg_3Si_4O_{12}$), is also known as soapstone and steatite; its theoretic composition when pure is: silica 63.5, magnesia 31.7, water 4.8.

It is used for cooking utensils, heating stoves, furnace linings, for fire-proof paints, and adulterating soap. Fibrous talc is used for weighting paper, in paints, and for making wall plasters.

It is also used as a lubricant, in polishing glass, in preparing toilet powders, and as a dressing on skins, felts, etc.

It occurs in large beds, usually in regions of metamorphic rocks.

St. Lawrence county in N. Y. is the principal producer of talc.

It is mined at Talcville in 400′ shafts, the vein being 18-20′ wide with granite walls. The output of fibrous talc in the state of New York in 1908 was 70,739 tons, valued at $697,390.

PRODUCTION OF TALC IN THE UNITED STATES IN 1908.

	Tons	
New York	70,739	$697,390
Virginia	19,616	458,252
Vermont	10,755	99,743
New Jersey and Pennsylvania	4,648	29,118
North Carolina	3,564	51,443
Other states	8,032	65,276
	117,354	$1,401,222

GRAPHITE.

Theoretically graphite is pure carbon, but analyses of a large number of samples show it to contain at most from 80 to 99% carbon.

As a refractory material it is used for making crucibles. It is shaped by being mixed with clay and turned on a wheel like pottery.

[14]C. H. Smyth, Jr.—The genesis of the talc deposits of St. Lawrence county, N. Y. School of Mines Quarterly, XVII, 333-341. July, 1896.

C. A. Waldo.—Talc and soapstone. The Mineral Industry, 1893, II, 603-606. New York, 1894.

C. H. Smyth, Jr.—Report on the talc industry of St. Lawrence county. 49th ann. rep. of the Regents, New York State Museum, for 1895, Vol. II, 661-671. Albany, 1898.

G. P. Merrill.—The nonmetallic minerals. Ann. rep. for 1899, U. S. Nat. Museum, 296-307. Washington, 1901. (Bibliography.)

LIME.

(See geology of lime at pages 322, 328.)

Lime alone "is one of the most refractory substances known, and no temperature has as yet been attained which has caused it to exhibit the slightest indication of fusion."—Percy, 134.

Crucibles made of unslaked lime are made by sawing the lumps into blocks and boring cavities in the center.

SILICA.

The Dinas fire-bricks are made of quartz-sand (96.73—98.31% pure silicia) from the Millstone Grit, in the Vale of Neath, near Swansea, Wales. They expand on being heated; fire-clay bricks contract when heated. Silica bricks cannot be used where the slag contains metallic oxides.

Any pure quartz may be used to manufacture silica bricks. Fire-clay is used to hold the sand together. Styrian silica bricks.

Availability of novaculites.

Occurrence and distribution of novaculites.

CHROME IRON.[15]

Chrome iron has lately come into use for furnace linings. It is crushed, washed, and made into bricks for this purpose.

(For the geology and references on this subject, see under Chromium, pages 206-208.

MICA.[16]

Uses.

The large sheets of mica are used for stove and furnace doors, and lamp chimneys; covers for the eyes of persons working at certain trades and using motor cars.

[15]W. Glenn.—Chromite as a hearth-lining for a furnace smelting copper-ore. Trans. Amer. Inst. Min. Eng., XXXI, 374-379. New York, 1902.

[16]J. A. Holmes.—Geology of the mica deposits of the United States. Engineering and Mining Journal, LXVII, 174. New York, 1899.

N. S. Shaler.—Mica mines of New England. Tenth Census, XV, 833-836. 1880.

C. Hanford Henderson.—Mica and the mica mines. Pop. Sci. Monthly, XLI, 652-665. New York, 1892.

J. A. Holmes.—Mica deposits of the United States. 20th ann. rep. U. S. Geological Survey, pt. VI continued, 691-707. Washington, 1899.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Mus., for 1899, 283-296. Washington, 1901.

D. B. Sterrett.—Mica. Mineral Resources of the U. S. for 1906, 1149-1163. Washington, 1907. For 1908, pt. II, 743-754. Washington, 1909.

G. W. Colles.—Mica and the mica industry. Jour. Franklin. Inst., CLX, 191-210, 275-295, 327-368. CLXI, 43-58, 81-100. Philadelphia, 1906.

Scrap mica is ground up and used for boiler-covering, insulating and fireproofing, and for a lubricant; also for an absorbent of nitroglycerin, in wall-paper, and in the manufacture of bronze powder, spangles on Christmas trees, and tinsel.

Composition and Character.

The mica of commerce is chiefly *muscovite* ($(H,K)\ AlSiO_4$), and has the following theoretical composition: silica 45.2, alumina 38.5, potash 11.8, water 4.5%.

Its transparency and flexibility.

Biotite is a black mica containing Mg, Fe, Al, K and silica, but seldom occurs in crystals large enough for commercial use.

Occurrence.

Mica of commercial importance occurs in the Appalachian Mountains in New Hampshire, Virginia, and North Carolina;[17] in the Black Hills of South Dakota,[18] in northern New Mexico and western Idaho.

It is found in pegmatite dikes in Archean gneisses and granites, generally cutting across the schistosity of the rocks.

The "books" or crystals are scattered through the mass, though they are sometimes near the walls.

Usually there is less than 1% of mica in the rock; sometimes as high as 10%.

Of the mined mica only from 1 to 10% is valuable as sheet mica.

The mica imported into this country comes chiefly from Great Britain, Canada,[19] and the East Indies.

During 1908 the average price of mica in New York was 24.1 cents per pound. For selected sizes the prices were as follows:

	Per pound
2 × 2 inches	$ .87
3 × 3 inches	2.75
4 × 6 inches	4.75
4 × 8 inches	6.75

[17]W. C. Kerr.—The mica veins of North Carolina. Trans. Amer. Inst. Min. Eng., VIII, 457-462. Easton, Pa., 1880.

[18]D. B. Sterrett.—Mica deposits of South Dakota. Bul. 380, U. S. Geological Survey, 382-397. Washington, 1909.

[19]E. T. Corkill.—Notes on the occurrences, production and uses of mica Jour. Can. Min. Inst., VII, 284-307. Toronto, 1905.

VALUE OF MICA PRODUCED AND IMPORTED INTO THE UNITED STATES.

Year	Production	Imports
1880	$127,825	$ 12,562
1890	75,000	207,375
1900	147,960	275,984
1902	118,849	466,332
1904	120,316	263,714
1906	274,990	1,042,608
1908	267,925	266,058

ABRASIVES.[1]

DIAMOND DUST.

(See under diamonds at page 456.)

CORUNDUM.[2]

Corundum for abrasive purposes; forms not available for precious stones.

Uses.

Powdered corundum is used as a polishing powder.

Emery, an impure variety containing iron, is used as a polishing powder and in making emery wheels.

Occurrence.

Corundum occurs in crystalline limestones and metamorphic rocks such as gneiss, schists, slates, etc. It occurs at various places in the Appalachian Mountain regions. Emery is mined at Chester, Mass., and corundum is mined at Laurel Creek, Georgia, at Corundum Hill, N. C.,[3] and at Salida, Colorado, where it occurs in a quartz vein in gneiss.

In 1898, 4,064 tons of corundum and emery were produced in the United States, valued at about $275,064. Since then the output has declined until in 1908 it was only 669 tons, worth $8,745.

The imports of emery in the United States in 1908 were valued at $248,399, which was less than half of the value of the imports for 1906.

Corundum was discovered in Canada in 1896.[4] The Canadian production in the year 1906 was valued at $204,973.

[1]Abrasives. Mineral Industry, VI, 11-26.

[2]Francis P. King.—A preliminary report on the corundum deposits of Georgia. Georgia Geological Survey, Bul. 2. Atlanta, 1894.

J. V. Lewis.—Corundum of the Appalachian crystalline belt. Trans. Amer. Min. Inst. Eng., XXV, 852-906. New York, 1896. (Bibliography.)

Corundum and emery. Mineral Industry, VII, 15-21.

A. Blue.—Corundum in Ontario. Trans. Amer. Inst. Min. Eng., XXVIII, 565-578. New York, 1899.

J. H. Pratt.—On the origin of the corundum associated with the peridotites of North Carolina. Amer. Jour. Sci., CLVI, 49-65. New Haven, 1898.

A. M. Stone.—Corundum mining in North Carolina. Engineering and Mining Journal, LXV, 490. New York, 1898.

Corundum and its uses. Nature, LIX, 558-559. London, 1899.

W. F. A. Thomae.—Emery, etc., in the Villayet of Aidin, Asia Minor. Trans. Amer. Inst. Min. Eng., XXVIII, 208-225. New York, 1899.

J. H. Pratt.—The occurrence and distribution of corundum in the U. S. Bul. 180, U. S. Geological Survey. Washington, 1901.

J. H. Pratt.—Corundum and its occurrence and distribution in the U. S. Bul. 269, U. S. Geological Survey. Washington, 1906.

[3]J. H. Pratt and J. V. Lewis.—Corundum and the peridotites of western North Carolina. North Carolina Geological Survey. Raleigh, 1905.

GARNET.[5]

(See under Precious Stones at page 466.)

The hardness of garnet is usually from 6.5 to 7.5, sometimes nearly 8.

Crushed garnet is used in preparing abrasive paper and belts for various kinds of high polishing, especially for dressing down leather in boot and shoe factories and for wood polishing.

The garnet for abrasive purposes mined in the Adirondack Mountains is of superior hardness; it occurs in large crystals in pockets in gneiss. The output of abrasive garnet in 1907 was 7,058 tons, worth $211,686.

SAND.[6]

The principal use of sand as an abrasive is in connection with gang-saws in sawing marble, limestone, and other stones.

PUMICE.[7]

Pumice is a very porous light lava, used in polishing various substances; most of the pumice of commerce comes from Mt. Vesuvius and the Lipari Islands, but it occurs in the vicinity of volcanoes, both active and extinct, in many parts of the world.

Nebraska, South Dakota, Wyoming, Idaho, Oregon, and California contain pumice, though it is not utilized in all these states.

In 1908 there were produced in the U. S. 10,569 tons, worth $39,287.

[4]M. B. Baker.—On the occurrence and development of corundum in Ontario. Jour. Can. Min. Inst. VII, 410-421. Toronto, 1905.

[5]F. C. Hooper.—Garnet as an abrasive material. School of Mines Quarterly, XVI, 124-127. New York, 1895.

H. C. Magnus. Abrasives of New York state. 23d rep. of the State Geologist for 1903, 158-179. Albany, 1904. (Bibliography.)

[6]Carborundum, crushed steel, and chilled iron shot, all of them artificial products, are largely used as abrasives for purposes similar to those of corundum, sand, etc.

[7]H. J. Johnston-Lavis.—The south Italian volcanoes, 67-71. Naples, 1891.

TRIPOLI.

So-called tripoli is fine grained diatomaceous earth, composed of the siliceous skeletons of microscopic plants. The plants are of both fresh and salt water origin.

Uses.

As a polishing powder. Its grains must be small enough to produce no perceptible scratch on the surface being polished.

As a cleaning agent in sapolic and scouring soaps.

As an absorbent for nitroglycerin in the manufacture of dynamite.

In blocks for blotters.

With shellac for making phonograph records.

Oil and water filters.

Fireproofing walls, safes, etc., and non-conductors for steam boilers and steam pipes.

Distribution and Occurrence.

Tripoli is found in the United States in Virginia near Richmond.

In California diatomaceous earth is abundant throughout the coast ranges. The deposits about the southwest end of the San Joaquin valley have a thickness of more than 5,000 feet. There are extensive beds of fresh water origin in Nevada.

In Newton county, Missouri,[8] a deposit of siliceous limestone from which the lime has been leached is called tripoli.

Certain deposits of siliceous powder found in Arkansas are derived from the novaculites by disintegration.

Diatomaceous earth occurs in Arizona,[9] New Mexico,[10] and New South Wales.[11]

It is limited to no particular geologic horizon, but the older deposits are liable to be too hard and compact to be useful as a polishing powder.

[8]C. E. Siebenthal and R. D. Mesler.—Tripoli deposits near Seneca, Missouri. Bul. 340, U. S. Geological Survey, 429-439. Washington, 1908. (Bibliography.)

[9]W. P. Blake.—Diatom-earth in Arizona. Trans. Amer. Inst. Min. Eng., XXXIII, 38-45. New York, 1903.

[10]C. L. Herrick.—The so-called Socorro tripoli. American Geologist, XVIII, 135-140. Sept., 1896.

[11]E. F. Pittmann.—The mineral resources of New South Wales, 425-431. Sydney, 1901.

WHETSTONES.[12]

Most whetstones are varieties of sandstone, schist, or novaculite, with silica as the abrasive element. They are generally of sedimentary origin. Their abrasive powers depend largely upon the size, hardness, and sharpness of the grit grains.

PROPERTIES OF WHETSTONES.

Effect of coarse-grained and fine-grained stones upon tools.[13]

Uniformity in size and distribution of the grains is essential.

The compactness of the stone is due to the particles being cemented, or to their being pressed together with or without cementing matter.

Character of grains.

In sandstones the grains are irregular and rough.

In schists the grains are small and angular and so arranged that the rock splits readily in one direction.

WEAR OF WHETSTONES.

The stones should wear faster than the metal being ground, in order to prevent the glazing of the stones.

Glazing is due to wearing away or dulling of the cutting points, and the clogging of the spaces between the cutting points, or both.

Hard fine-grained stones are most apt to glaze.

Fast wearing stone.

Slow wearing stone.

Oilstones are so called because oil is used to float away the abraded metal.

They are very fine-grained.

Scythe-stones are generally used dry.

Water is sufficient to carry away the metal from coarse-grained stones.

VARIETIES OF WHETSTONES.

Sandstones furnish most of the whetstones of the United States.

Labrador stone from Cortland county, New York.

Hindostan stone from Indiana.[14]

Adamscobite stone from Pierce City, Missouri.

Schists furnish scythe-stones especially.

[12]L. S. Griswold.—Whetstones and the novaculites of Arkansas. Geological Survey of Arkansas for 1890, III. Little Rock, 1892.

E. M. Kindle.—The whetstone and grindstone rocks of Indiana. Twentieth ann. rep. Geological and Natural History Survey of Indiana, 1895, 329-368. Indianapolis, 1896.

[13]A. A. Julien.—Effect of various honestones on the edge of steel tools. Jour. Applied Microscopy, VI, 2653-2661. Rochester, 1910.

[14]O. C. Salyards.—At an Indiana whetstone quarry. Stone, XIII, 539-543. 1896.

Whetslates.

Novaculites: the novaculites of Arkansas furnish the finest oilstones and honestones in the world.

The Turkey stone.

Whetstones of the United States.

Arkansas, Indiana, Vermont, and New Hampshire furnish most of the whetstones of the United States.

The Arkansas stone (novaculite) is exceedingly hard and is adapted to grinding fine edge tools of all sorts.

The "Arkansas stone."
The "Ouachita stone."

Indiana.
Oilstones obtained from Orange county are very fine-grained sandstone of Carboniferous age.

Vermont.
Whetstones and scythe-stones are principally mica schists of Cambrian and Huronian ages.

New Hampshire.
Scythe-stones and other whetstones from Grafton county are of mica schists of Huronian and Silurian ages.

New York, Cortland county, produces Labrador stone, a fine-grained green sandstone.

Missouri produces Adamscobite stone at Pierce City.

Ohio, at Berea, Cuyahoga county, and Michigan, at Grindstone City, Huron county, furnish sandstone scythe-stones.

GRINDSTONES.

Grindstones are made from sharp-grained compact sandstones; grains should be of uniform size, and the stone should be soft enough to wear without glazing.

Most of the grindstones of the United States are produced in Ohio, Michigan, South Dakota, and California.

Many other states supply stones for local demands.

OHIO.

Grindstones are quarried in northern part of state from the Berea Grit which is in the Lower Carboniferous. Cuyahoga, Lorain, and Summit counties are the principal producers; there are also quarries in Stark and Washington counties.

MICHIGAN.

The great grindstone quarries of Michigan are at Grindstone City, 90 miles north of Port Huron; the sandstone used is free from foreign matter and fine-grained.

MILLSTONES.

Millstones are not properly abrasives. They are made from hard, sharp-grained, tough rocks, of coarse texture.

Quartzitic conglomerates are frequently used.

Millstones in the United States are produced principally in New York, Pennsylvania, Virginia, and Ohio.

Buhrstone is a quartz conglomerate with an open cellular structure especially adapted to the manufacture of millstones. The best qualities of buhrstone come from the Paris basin (Tertiary). Somewhat similar stones occur in Alabama, Arkansas, Georgia, and South Carolina.

Uses.

In grinding grain.

Crushing other materials.

Effect of the roller process in the manufacture of flour on the demand for millstones.

CARBORUNDUM.

Carborundum is an artificial product made by fusing in an electric furnace, glass-sand or silica, pulverized coke and sawdust.

MISCELLANEOUS MINERALS.

SALT.[1]

Common salt (NaCl), sodium 39.4, chlorine 60.6, as a geological product, occurs as salt water or brine, or as rock-salt interstratified with sedimentary rocks.

Uses.

Preserving meats, and domestic purposes.
Manufacture of soda.
Chloridizing ores in metallurgy.
Manufacture of chlorine; glaze of pottery.

Origin.

By the natural evaporation of salt water.[2]
Thick deposits of rock-salt by high tides flowing into closed basins in arid regions, or by evaporation that produces a constant influx from a larger to a smaller basin.[3]
Solutions containing salt rising toward the surface and cooling and depositing it.

Distribution.

Salt occurs in sedimentary rocks from the Lower Silurian to those now forming, and in almost all countries.

Among the most remarkable salt deposits known are those of:
Galicia and Transylvania in Austria-Hungary.
At Wieliczka,[4] Galicia, it is mined and stoped out like coal.
The Austrian and Bavarian Alps.
Western Germany at Sperenberg, near Berlin, 3,600′.[5]
At Cardona, near Barcelona, Spain, is an open quarry of rock-salt.[6]

[1]Spons' encyclopedia of industrial arts, etc. Salt, II, 1710-1740. London, 1882.
E. W. Parker.—Salt. 12th Census of the U. S., IX, pt. III, 529-542. Washington, 1902.
G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Mus. for 1899, 195-213. Washington, 1901.

[2]C. V. Bellamy.—A description of the salt-lake of Larnaca, in the island of Cyprus. Quar. Jour. Geol. Soc., LVI, 745-758. London, Nov., 1900.

[3]F. Beaufort.—Karamania, 283-284. London, 1818.

[4]J. H. Vivian.—Remarks on the salt mines of Wielitska in Poland, and of Salzburg in Germany. Trans. Royal Geological Society of Cornwall, I, 154-167. London, 1818.

[5]H. M. Cadell.—The salt deposits of Stassfurt. Trans. Edin. Geol. Soc., V, pt. I, 92-103. Edinburgh, 1885.

[6]L. M. Vidal.—Compte-rendu de l'excursion au gisement de sel de Cardona. Bul. Soc. Géol. de France, 3d ser., XXVI, 725-731. Paris, 1898.

In Peru[7] it is mined.
Springs and wells in China.[8]

Salt in the United States.[9]

New York.[10]

In the Onondaga district near Syracuse the brine comes from the Salina beds.

In the Warsaw district, which is in Wyoming, Genesee, and Livingston counties a bed of rock-salt in the Upper Silurian from 70′ to 318′ thick underlies hundreds of square miles. Shafts to reach it are from 825′ to 1,430′ deep.

Michigan.[11]

Rock-salt and brine from Carboniferous limestone, accumulating in the Marshall sandstone below the gypsum.[12]

Structural features of the Peninsula syncline.
The deeper brines are stronger.
One well, 1,964′ deep, found 32′ rock-salt in Manistee county.
Wells average 880′ in depth.

Kansas.[13]

Rock-salt of the Trias underlies many counties in the central and southern parts of the state; deposits lenticular, from a few inches to 200′ thick; from 400′-1,000′ below the surface.

[7]Robert Peele, Jr.—A Peruvian salt mine. School of Mines Quarterly, XV, 219-221. New York, 1894.

[8]Louis Coldre.—Les salines . . . du se-Tchoan. Annales des Mines. 8me ser. XIX, 441-528. Paris, 1891.

[9]Thomas M. Chatard.—Salt-making processes in the United States. Seventh ann. rep. U. S. Geological Survey, 497-535. Washington, 1888.

W. C. Phalen.—Salt in the U. S. Mineral Resources of the U. S. for 1908, pt II, 643-657. (Bibliography.) Washington, 1909.

[10]F. J. H. Merrill.—Salt and gypsum industries of New York. Bul. New York State Museum, III, no. 11. Albany, 1893.

D. D. Luther.—The Livonia salt shaft. Rep. State Geologist (of New York) for 1893, 11-130. Albany, 1894.

D. D. Luther.—The brine springs and salt wells of New York, and the geology of the salt district. 16th ann. rep. State Geologist (of New York) for 1896, 175-226. Albany, 1899.

[11]A. Winchell.—Geological studies. Geology of salt, 186-193. Chicago, 1889.

L. L. Hubbard.—The origin of salt, etc. Geol. Sur. Mich., V, pt. II. Lansing, 1895.

[12]G. P. Grimsley.—A theory of origin for the Michigan gypsum deposits. American Geologist, XXXIV, 378-387. Dec., 1904.

[13]Robert Hay.—Geology of Kansas salt. (No date.)

W. R. Crane.—Rock salt mining in Kansas. Engineering and Mining Journal, LXXV, 859-860. New York, 1903.

S. Ainsworth.—The rock salt mining industry in Kansas. Engineering and Mining Journal, LXXXVIII, 454-456. New York, 1909.

C. M. Young.—Notes on the evaporated salt industry in Kansas. Engineering and Mining Journal, LXXXVIII, 558-561. New York, 1909.

Utah.

Most of the salt is made from the waters of Salt Lake.[14] How Salt Lake came to be salty.

Louisiana[15] *and Texas.*

The Petite Anse deposits; Tertiary; structure.

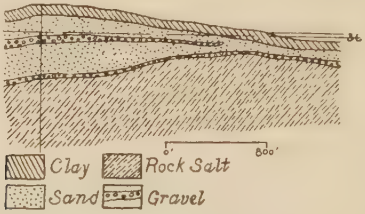

Fig. 113.—Section showing the order of the deposits accompanying the rock-salt beds of Louisiana. (Lucas.)

California.[16]

Salt is produced from solar evaporation of sea water in Alameda, San Mateo, Los Angeles, and San Diego counties.

Ohio, West Virginia, Idaho, Nevada, and *Oklahoma* produce small quantities of salt.

STATISTICS OF THE CHIEF SALT-PRODUCING STATES.

	1897 Barrels	1908 Barrels
New York	6,805,854	9,076,743
Michigan	3,993,225	10,194,279
Ohio	1,575,414	3,427,478
Kansas	1,538,327	2,588,814
Utah	405,179	242,678
California	470,893	899,028
Louisiana	.....	947,129

[14]J. E. Talmage.—The great Salt Lake, past and present. Utah University Quarterly, II, 137-152. Sept., 1896.

[15]A. F. Lucas.—Rock-salt in Louisiana. Trans. Amer. Inst. Min. Eng., XXIX, 462-474. New York, 1900.

G. D. Harris.—The geological occurrence of rock salt in Louisiana and east Texas. Economic Geology, IV, 12-34. Jan., 1909.

[16]E. C. Eckel.—The salt industry in Utah and California. Bul. 225, U. S. Geological Survey, 490-495. Washington, 1904.

G. E. Bailey.—The saline deposits of California. Bul. 24, California State Mining Bureau. Sacramento, 1902.

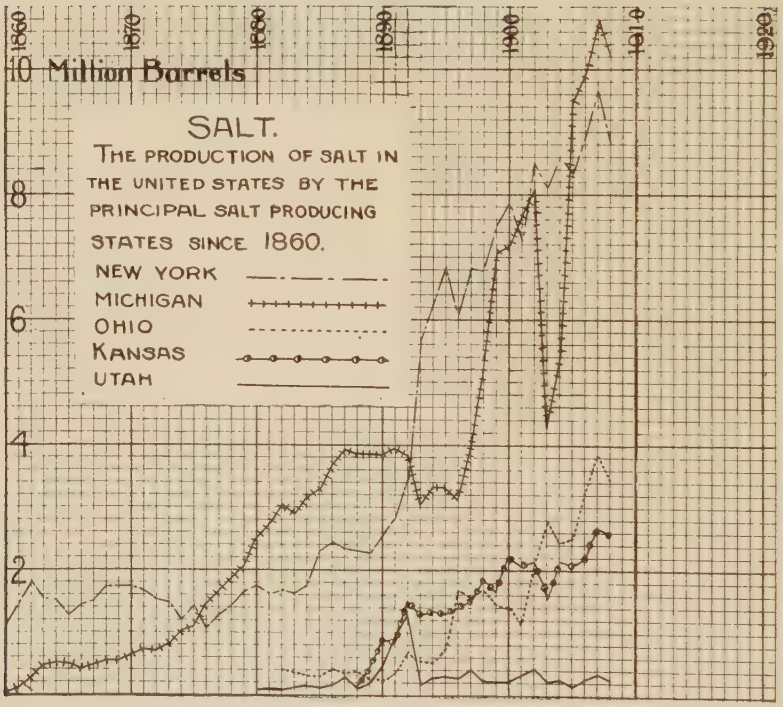
1860
1870
1880
1890
1900
1910
1920
10 Million Barrels
8
6
4
2
SALT.
THE PRODUCTION OF SALT IN THE UNITED STATES BY THE PRINCIPAL SALT PRODUCING STATES SINCE 1860.
NEW YORK
MICHIGAN
OHIO
KANSAS
UTAH

Fig. 114.

BORAX.

Borax is sodium biborate ($Na_2B_4O_7 + 10\ H_2O$): boron trioxide 36.6, soda 16.2, water 47.2).

Uses.[1]

As an antiseptic and in medicine.
In the manufacture of enamels for pottery.
In the manufacture of soap.
As a flux in metallurgy.
In the welding of steel.

Occurrence and Origin.

Most of the borax of commerce is from the native borax or tincal, a borate of soda, from colemanite, a borate of lime, and ulexite, borates of lime and soda.

These minerals occur as crystals in the mud at the bottom of borax lakes, and in the dry beds of old borax lakes, or in loose or massive form.

Borax is also made from the underground waters that have passed over or through rocks containing soluble borates.

The borax in the lake water, in the mud at the bottoms of the lakes, or in the ancient lake bottoms has been concentrated by evaporation from waters containing boron in solution.

Borax occurs as a geological deposit only in arid regions such as Asia Minor, Thibet, northern Chile[2] and the dry portion of southeastern California.

Borax in the United States.[3]

California.[4]

Discovered by Dr. Veatch at Borax Lake in Lake county in 1856. Searles Borax marsh, San Bernardino county, the dry bed of an old lake; the old shore terraces are 600′ above.

[1]C. G. Yale.—Borax. Mineral Resources of the U. S. for 1904, 1017-1028. Washington, 1905.

[2]Boratos, Estadistica minera de Chile en 1903, 298-310. Santiago, 1905.

[3]C. G. Yale.—Borax. Mineral Resources of the United States for 1889-90, 494-506. Washington, 1892.

Henry G. Hanks.—Report on the borax deposits of California and Nevada. Third ann. rep. State Mineralogist of California. Sacramento, 1883.

Borax. Fourth ann. rep. State Mineralogist of California, 80-93. Sacramento, 1884.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Museum for 1899, 396-402. Washington, 1901.

Chas. R. Keyes.—Borax-deposits of the U. S. Trans. Amer. Inst. Min. Eng., XL, 674-710. New York, 1910.

[4]G. E. Bailey.—The saline deposits of California. Bul. 24, California State Mining Bureau, 33-90. Sacramento, 1902.

Igneous rocks of the surrounding country.

Succession of deposits in the bottoms of valleys.

At Calico, San Bernardino county, is a lime borate (colemanite) deposit interbedded with other sedimentary rocks. It is mined by shafts and drifts.

Death Valley[5] in Inyo county.

Saline Valley, Inyo county, in marshes.

Water containing borax in solution is pumped from wells in the valleys and evaporated.

Nevada.

Lake near Ragtown; Sand Springs.

Oregon.

At the Cheto mine, in Curry county, *priceite* occurs as boulders weighing from a few ounces to several hundred pounds.

Borax in a marsh in Harney county.[6]

The borax industry of the United States began in California in 1865.

EXAMPLES OF BORAX PRODUCTION IN THE UNITED STATES.

Year	Tons
1878	1,401
1888	3,795
1898	8,000
1906	58,173
1908	25,000

[5]M. R. Campbell.—Reconnaissance of the borax deposits of Death valley and Mojave desert. Bul. 200, U. S. Geological Survey. Washington, 1902.

E. Hart.—Death valley, California, and its borax industry. Trans. Amer. Ceramic Soc., V, 64-73. Columbus, 1903.

[6]W. B. Dennis.—A borax mine in southern Oregon. Enigneering and Mining Journal, LXXIII, 581. New York, 1902.

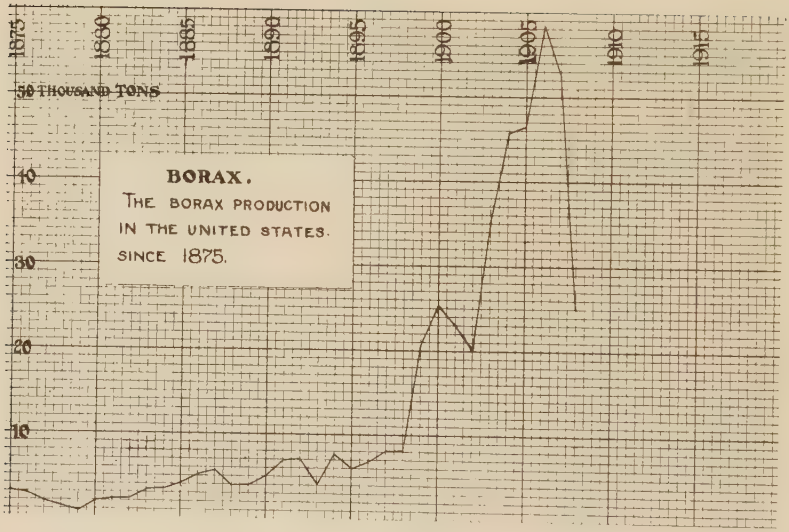
1875
1880
1885
1890
1895
1900
1905
1910
1915
50 THOUSAND TONS
40
30
20
10
BORAX.
THE BORAX PRODUCTION
IN THE UNITED STATES.
SINCE 1875.

Fig. 115.

SODA.[1]

Most of the soda of commerce is an artificial product manufactured from common salt.

Natural soda is the residue from the evaporation of alkaline waters and consists of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) in varying proportions, mixed with impurities, chiefly sodium chloride (NaCl) and sodium sulphate (Na_2SO_4).

The chief natural soda minerals are: *trona* or *urao* (Na_2CO_3. $NaHCO_3 + 2H_2O$): carbon dioxide 38.9, soda 41.2, water 19.9; *natron* ($Na_2CO_3 + 10H_2O$): carbon dioxide 15.4, soda 21.7, water 62.9; and *thermonatrite* ($Na_2CO_3 + H_2O$): carbon dioxide 35.5, soda 50.0, water 14.5.

Origin.

Soda is produced by the evaporation and concentration of surface waters flowing from or over igneous rocks containing soda in the constituent minerals.

It is to be expected in any country where both the geologic and the climatic conditions are favorable.

Natural Soda in the United States.

It forms a large part of the so-called alkali of the arid regions of the western United States.

Nevada: two lakes at Ragtown.

California: Mono Lake in Inyo county.[3]

Oregon: Albert and Summer Lakes.

Wyoming[4]: deposits containing 34% sodium and magnesium sulphate cover great areas in south-central Wyoming.

[1]Soda products. 12th Census, X, 539-543. Washington, 1902.

[2]Thomas M. Chatard.—Natural soda; its occurrence and utilization. Bul. 60, U. S. Geological Survey, 27-101. Washington, 1890.

[3]G. E. Bailey.—The saline deposits of California. Bul. 24, California State Mining Bureau. Sacramento, 1902.

[4]T. T. Read.—The alkali deposits of Wyoming. American Geologist, XXXIV, 164-169. Minneapolis, 1904.

SULPHUR.[1]

Uses.

Manufacture of gunpowder.
Manufacture of wood pulp.[2]
Sulphuric acid.[3]
Matches, paper, fertilizers, insecticides.
Medicine.

Occurrence.

Native and in combination with other elements.
Native sulphur.
1. In volcanic regions deposited from sulphurous gases.
2. As an alteration of gypsum.

Sulphur of organic origin.[4]
In combination its most important form as a source of sulphur is that of iron pyrites, which occurs in veins, beds, and irregular pockets. (See *Iron Pyrites.*)

Distribution.

Geologic.
Native sulphur is found principally in Tertiary, Pleistocene, and recent deposits.

Geographic.
Sicily is the principal source of native sulphur.[5]
The mines spread over an area of 5,000 square miles, the sulphur occurring in veins and masses from three to ten feet thick, in Miocene limestone. Some petroleum and bitumen is associated with the sulphur.
Antiquated methods of exploitation.
Rock containing less than 8% sulphur is not worked.

[1]W. C. Phalen.—Sulphur and pyrite. Mineral Resources of the U. S. for 1907, pt. II, 673-683. Washington, 1908. Same for 1908, pt. II, 659-668. Washington, 1909.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Museum, 1899, 174-181. Washington, 1901.

E. W. Parker.—Sulphur and pyrite. 20th ann. rep. U. S. Geological Survey, pt. VI, continued, 641-655. Washington, 1899.

[2]Herman Frasch.—Brimstone versus pyrite for wood-pulp manufacture. Engineering and Mining Journal, LXXX, 1165-1166. New York, 1905.

[3]Dr. R. Kneitsch.—Sulphuric acid and its manufacture by the contact-process. Pop. Sci. Monthly, LXI, 24-31. New York, 1902.

[4]On sulphur formed by bacteria, see American Naturalist, XXXII, 456-457. June, 1898.

[5]Giovanni Aichino.—The sulphur industry of Italy. The Mineral Industry for 1899, VIII, 592-616. New York, 1900. (Bibliography.)

Sulphur deposits of Japan of the solfataric type.

The island of Hokkaido is the principal source of supply.

Mexico, New Zealand: sulphur occurs about several volcanic mountains, but little is produced.

In Iceland[6] solfataric.

New Hebrides Islands: sulphur occurs on a volcanic cone on the Isle of Tauna.

Sulphur in the United States.[7]

Large deposits on Kodiak Island, Alaska, are not worked at present. There are deposits also on Unalaska.

California: in connection with igneous rocks at Sulphur Bank, Lake county; also in Colusa and Kern counties and on the western rim of the Salton desert in San Diego county.

Nevada: in the Humboldt mountains, in irregular masses associated with gypsum, and east of the south end of Big Smoky valley.[8]

Utah: the Cove Creek mines are 26 miles east of Black Rock, in a volcanic region. The sulphur is in veins, and impregnates a tuff in a zone of faulting and volcanic activity. The sulphur rock is 30′ thick and less.

Louisiana is the chief source of sulphur in the United States.[9] The deposits are in Cretaceous sediments. Peculiar method of mining by the use of hot water.

Texas[10]: sulphur occurs near Guadalupe.

Wyoming has sulphur deposits near Cody and near Thermopolis.[11]

THE PRODUCTION AND IMPORTS OF SULPHUR IN THE UNITED STATES.

	Production.		*Imports.*	
Year	Pounds	Value	Pounds	Value
1880	536	$ 21,000	98,751	$2,034,899
1890	1,071	39,600	131,300	2,683,971
1898	1,071	32,960	184,250	3,069,924
1904	127,292	2,663,760	129,553	2,511,269
1908	369,444	6,668,215	21,136	362,379

[6]W. L. Watts.—Across the Vatna Jökull, or scenes in Iceland, 113-116, 129, 141, 154. London, 1876.

[7]J. F. Kemp.—Sulphur. Mineral Industry for 1893, II, 585-602. New York, 1894.

[8]H. W. Turner.—The Esmeralda formation, a fresh-water lake deposit in Nevada. Twenty-first ann. rep. U. S. Geological Survey, pt. II, 207-208. Washington, 1900.

[9]D. A. Willey.—The sulphur mines of Louisiana. Engineering and Mining Journal, LXXXIV, 1107-1109. New York, 1907.

[10]E. A. Smith.—Notes on native sulphur in Texas. Science, III, new series, 657-659, New York, 1896.

Sulphur . . . in Trans-Pecos, Texas. Bul. 2, Univ. of Texas Min. Survey. Austin, 1902.

[11]W. C. Phalen.—Sulphur and pyrite. Mineral Resources of the U. S., for 1907, pt. II, 674-675; same for 1908, pt. II, 660-661.

BARYTES.[1]

Barite, barytes, or heavy spar is the sulphate of barium ($BaSO_4$): sulphur trioxide 34.3, baryta 65.7.

Uses.

Manufacture of paint as a substitute for white lead and zinc oxide. Weighting paper and putty.

Lithophone, used as a pigment for special purposes, is a mixture of barium sulphate (68%), zinc (7.28), and zinc sulphide (24.85%).

Occurrence and Distribution.

It occurs as vein-stone associated with ores of lead, copper, silver, etc., as pockets in limestone, and as amygdules in eruptive rocks. In the United States the principal deposits worked are in Missouri,[2] Tennessee and Virginia.[3] It occurs also in North Carolina, South Carolina, Georgia, Kentucky, Arkansas, New Jersey, and in many other states.

Missouri is the leader in the production of barytes.[2]

In Tennessee, the second in production of barytes, it is mined from clays formed by the decomposition of the containing rock.

In Virginia there are many occurrences of the mineral in lenticular and vein-like masses in pockets and fracture zones in limestone. It is a replacement of the limestones by shallow solutions and the mineral is derived from the limestone.

At Five Islands, Nova Scotia.[4]

Production of crude barytes in the United States in 1908 was 38,527 short tons, worth $120,442, which was much less than the output of the preceding year. Imports in 1908 amounted to 17,062 tons.

[1]E. F. Burchard.—Barytes and strontium. Mineral Resources of the United States for 1907, pt. II, 685-696. Washington, 1908. (Bibliography.) Same for 1908, pt. II, 669-673. Washington, 1909.

[2]A. A. Steel.—The geology, mining, and preparation of barite in Washington county, Mo. Trans. Amer. Inst. Min. Eng., XL, 711-743. New York, 1910.

[3]T. L. Watson.—Geology of the Virginia barite deposits. Trans. Amer. Inst. Min. Eng., XXXVIII, 710-733. New York, 1908.

E. K. Judd.—The barytes industry of the south. Engineering and Mining Journal, LXXXIII, 751-753. New York, 1907.

[4]W. S. Hutchinson.—Barytes deposits at Five Islands, Nova Scotia. Engineering and Mining Journal, LXXXIV, 825-826. New York, 1907.

SODA NITER.

Soda niter is sodium nitrate ($Na_2O + N_2O_5$): nitrogen pentoxide 63.5, soda 36.5.

Uses.

Manufacture of nitric acid.
Potting of sulphuric acid.
Manufacture of potassium nitrate.
Medicine.
Fertilizers.

Occurrence.[1]

In the deserts of northern Chile,[2] Peru,[3] and Bolivia, associated with gypsum and salt.

The deposits are mostly near the surface, and are worked in open pits of irregular form.

The artificial production of nitrate of lime in Norway.[4]

[1] A. Pissis.—Nitrate and guano deposits in the desert of Atacama (Chile). London, 1878.

A. Muntz.—Recherches sur la formation des gisements de nitrate de soude. Comptes Rendus, CI, 1265. Paris, 1885.

G. E. Brown.—The nitrate deposits of Chile. Mining Journal, LXXXVI, 259-263. London, 1909.

[2] The nitrate of soda industry (in Chile). Engineering and Mining Journal, LXXI, 241-242. New York, 1901.

[3] A. J. Duffield.—Peru in the guano age, 102-119. London, 1877.

[4] J. B. C. Kershaw.—The artificial production of nitrate of lime. Science Progress, II, 361-364. London, Oct. 1906.

A. J. Lotka.—The manufacture of nitrates from air.—Engineering and Mining Journal, LXXXIII, 848. New York, 1907.

Processes for the fixation of atmospheric nitrogen. Nature, LXXXI, 143-144. London, July 29, 1909.

NITER OR SALTPETER.

Niter of saltpeter is nitrate of potash (KNO_3): nitrogen pentoxide 53.5, potash 46.5.

Uses.

Manufacture of gunpowder and fireworks.
Medicinal purposes.
Antiseptic.
Fertilizer.

Occurrence and Distribution.[1]

It occurs in shallow or surface deposits, mingled with the dry earth in caves. The large deposits are found near the surface and in crevices between loose stones in certain arid regions. The niter is prepared by leaching it from the crude materials and redepositing from the solutions.

Relation to organic matter.

Iodine is a by-product.

Chile[2] in the vicinity of Iquique has the largest known deposits.

In the caves[3] of Ceylon and Teneriffe; also in caves of Minas Geraes, and Bahia in Brazil; Kentucky, Tennessee, Arkansas, and Wyoming.

Stassfurt mines of Germany.

[1]Müntz et Marcano.—Sur la formation des terres nitrées dans les régions tropicales. Comptes Rendus, CI, 65. Paris, 1885.

Muntz.—Recherches sur la formation des gisements de nitrate de soude. Comptes Rendus, CI, 1265. Paris, 1885.

[2]R A. F. Penrose Jr.—The nitrate deposits of Chile. Journal of Geology, XVIII, 1-32. Chicago, 1910.

Mark G. Lamb.—The niter industry of Chile. Engineering and Mining Journal, XC, 18-22. New York, 1910.

[3]W. H. Hess.—The origin of nitrates in cavern earths. Journal of Geology, VIII, 129-134. Chicago, 1900.

H. W. Nichols.—Nitrates in cave earths. Journal of Geology, IX, 236-243. Chicago, 1901.

OZOKERITE OR OZOCERITE.[1]

Ozokerite or mineral tar is partially oxidized petroleum. It is as hard as beeswax, and has the odor of petroleum.

Uses.

Its principal use is for making paraffine candles; other uses are wax matches, as a lubricant, protecting metals from rust, and for insulating purposes, calking ships, adulterating beeswax, making wax dolls, varnishes, and blacking.

Occurrence.

It is always associated with petroleum in sedimentary rocks.

The principal known deposits are in the Tertiary sandstones of Galicia, Austria, north of the Carpathian Mountains, where it fills thin, irregular veins. It gets softer with depth on account of the greater oxidation near the surface.

American Deposits.

In the Wasatch Mountains, 100 miles east of Salt Lake, are the only known American deposits of any importance; they are not worked at present.

It occurs in vertical fissures in crushed Tertiary strata.[2]

It probably occurs in the petroleum and asphaltum regions of southern California.

[1] J. S. Newberry.—The origin of the carbonaceous matter in bituminous shales. Annals of the New York Acad. of Sci., II, 357-367. New York, 1882.

S. F. Peckham.—(Notes on the origin of bitumens.) Proc. Amer. Phil. Soc., X, 445-462. Philadelphia, 1865-1868; XXXVII, 108-139. Philadelphia, 1898; Amer. Jour Sci., XCVIII, 131-133. New Haven, 1869; XCVIII, 362-370. New Haven, 1869. (References.)

L. Lartet.—Sur les gites bitumineux de la Judee, etc. Bul. Soc. Géol. de France, 2me sér., XXIV, 12-32. Paris, 1867.

Edward B. Gosling.—A treatise on ozokerite. The School of Mines Quarterly XVI, 41-68. New York, 1895.

[2] J. A. Taff and C. D. Smith.—Ozokerite in Utah. Bul. 285, U. S. Geological Survey, 369-372. Washington, 1906.

J. E. Clayton.—Ozokerite or mineral wax. Engineering and Mining Journal, XXXIX, 168-169. New York, 1885.

GRAPHITE, PLUMBAGO, OR BLACK LEAD.[1]

Graphite is pure carbon, having a greasy feel and a black metallic lustre.

Uses.[2]

Best qualities are used for lead pencils and crayons.
An important use is for making crucibles and other refractory materials.
As a lubricant that is not affected by cold, heat, or air.[3]
Inferior grades are used for stove polish.
In electrotyping.
Foundry facings.
Graphite paint.

Occurrence.

Graphite is most abundant in old metamorphic rocks where it occurs as vein-like deposits and in bed-like deposits.
Theory of its organic origin[4] from hydro-carbons.
1. The liquid theory of Diersche.
2. The gaseous theory of Walther.

Theory of its chemical production.[5]
Graphite found in pig iron; why.

Distribution.

Widely distributed, but mined in few countries.
The leading producers in the order of their importance at present are: Austria, Ceylon, Germany, Italy, United States, and Japan.
The product of the Alibert mine in Siberia is used for the best pencils.
The Ceylon product is noted for its purity.

[1]Fritz Cirkel.—Graphite; its properties, occurrence, refining, and uses. Dept. of Mines, Canada. Ottawa, 1907. (Bibliography.)

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Museum, 1899, 168-174. Washington, 1901.

J. A Walker.—Graphite. Mineral Resources of the United States, 1883-1884, 915-919. Washington, 1885.

E. Weinschenk.—Mémoire sur l'histoire géologique du graphite. Compt. Rend. Congrès. Géol. Internat., I, 447-457. Paris, 1901.

[2]Dr. Heinrich Weger.—Der graphit und seine wichtigsten Annendungen. Berlin, 1872.

[3]Graphite. Mineral Industry, VII, 382-387. New York, 1899.

[4]A. Taylor.—(Coal converted into graphite.) Trans. Edin. Geol. Soc., II, 368. Edinburgh, 1874.

I. C. White.—Origin of grahamite. Bul. Geol. Soc. Amer., X, 277-284. Rochester, 1899.

J. S. Newberry.—The origin of graphite. School of Mines Quarterly, VIII, 334-335. New York, 1887.

[5]J. F. Kemp.—Pre-Cambrian sediments in the Adirondacks. Science, new series, XII, 94-96. New York, 1900.

Austria.[6]

The Austrian graphite deposits are in gneiss and schist; in places they are eighteen feet thick.

Ceylon.[7]

The veins are in gneiss; some of the graphite 99.79 per cent carbon.

Germany.

In Bavaria a vein in gneiss is sometimes 16 feet thick; the product is impure.

Japan, Italy, India,[8] *Queensland.*[9]

Canada.[10]

In veins and thin seams in Laurentian rocks; the most important Canadian deposits are in the Province of Quebec.

United States.

Many occurrences of graphite in the United States, but the only mines worked are those at Graphite, near Ticonderoga, N. Y., and at Cranston, R. I.[11] At the latter place it is associated with anthracite.

It occurs in the Coal Measures of New Mexico.

In Gunnison county, Colorado, are graphite beds 2 feet thick.

In Albany county, Wyoming, it occurs in veins.

In California it is mixed with kaolin.

Importance and difficulty of separation from any substance that is difficult to settle in water.

The possible artificial production of graphite.[12]

[6]M. Bonnefoy.—La géologie et l'exploitation des gites de graphite de la Boheme Méridionale. Annales des Mines, 7 ser., XV, 157-208. Paris, 1879.

[7]A. K. Coomára-Swámy.—On Ceylon rocks and graphite. Quar. Jour. Geol. Soc., LVI, 590-615. London, 1890. (Bibliography.)

[8]V. Ball.—A manual of the geology of India, III, Economic Geology, 50-58. Calcutta, 1881.

[9]B. Dunstan.—Graphite in Queensland. Pub. 203, Geological Survey of Queensland. Brisbane, 1906.

[10]Quar. Jour. Geol. Soc., XXV, 406. London, 1869.

J. W. Dawson.—On the graphite of the Laurentian of Canada. American Journal of Science, C, 130-134. New Haven, 1870.

[11]R. H. Palmer.—A graphite mine. Engineering and Mining Journal, LXVIII, 694. New York, 1899.

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E. S. Bastin.—Graphite. Mineral Resources of the U. S. for 1908, pt. II, 717-738. Washington, 1909.

[12]F. J. Fitzgerald.—The conversion of amorphus carbon to graphite. Jour. Franklin Inst., CLIV, 321-348. Philadelphia, 1902.

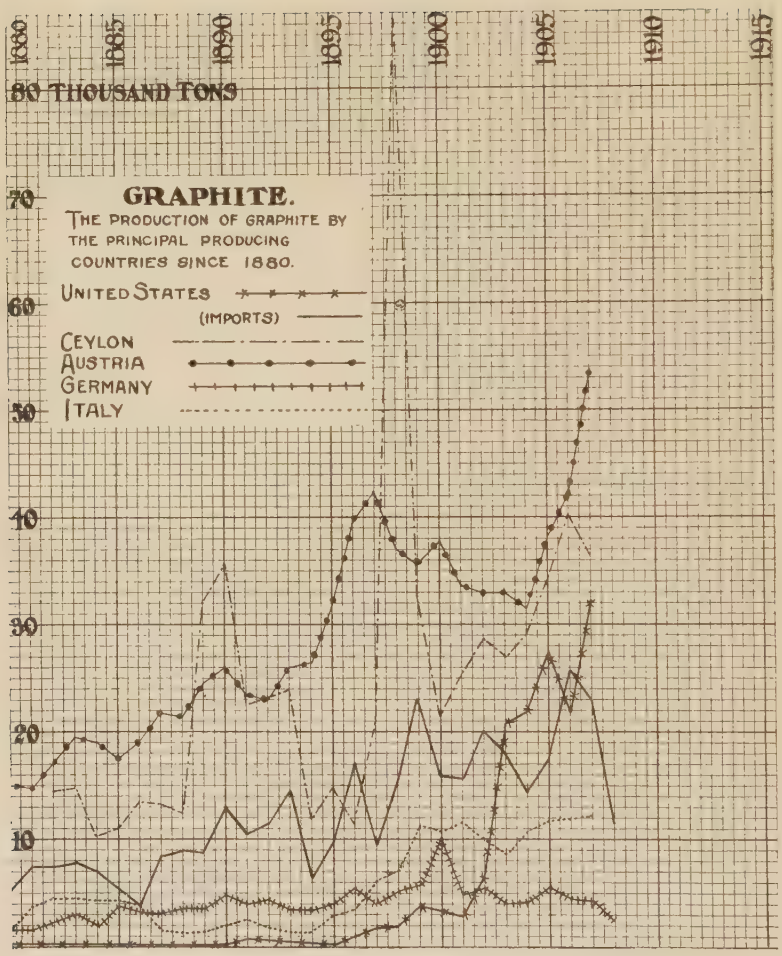
GRAPHITE.
THE PRODUCTION OF GRAPHITE BY THE PRINCIPAL PRODUCING COUNTRIES SINCE 1880.
UNITED STATES
(IMPORTS)
CEYLON
AUSTRIA
GERMANY
ITALY
80 THOUSAND TONS
70
60
50
40
30
20
10
1880
1885
1890
1895
1900
1905
1910
1915

Fig. 116.

BAUXITE.[1]

Bauxite is hydrate of alumina ($Al_2O_3 2H_2O$); essentially alumina 73.9, water 26.1%. It is massive, oölitic, or earthy; white, gray, red or mottled.

Uses.

Manufacture of alum,[2] sulphate of alumina, and aluminum,[3] and as a refractory material or for increasing the refractoriness of fire-clays.

Occurrence.

In southern France it occurs in massive beds at the junctions between the Triassic and Jurassic; in Italy;[4] in Arkansas[5] as beds and irregular masses in Tertiary rocks, and as alteration products from syenites sometimes covering many acres; in Alabama as beds interstratified with Paleozoic rocks.

Bauxite occurs in Georgia[6] between Cretaceous and Tertiary rocks.

[1] G. P. Merrill.—The nonmetallic minerals. Rep. for 1899, U. S. Nat. Museum, 229-239. Washington, 1901.

[2] Alums. 12th Census of the U. S., X, 546-548. Washington, 1902.

[3] J. W. Richards.—Aluminum: its history, occurrences, properties, metallurgy, etc. Philadelphia, 1890.

[4] G. Aichino.—La bauxité. Rassegna Mineraria, XV, 15, 16, 17, and 18. Torino, 1902.

[5] J. C. Branner.—The bauxite deposits of Arkansas. Journal of Geology, V, no. 3, 263-289. Chicago, 1897. (Bibliography.)

C. W. Hayes.—The Arkansas bauxite deposits. Twenty-first ann. rep. U. S. Geological Survey, pt. III, 435-472. Washington, 1901.

[6] The bauxite of Wilkinson county, Georgia. Bul. 18, Geological Survey of Georgia, 430-447. Atlanta, 1909.

MONAZITE.[1]

Monazite is a phosphate of cerium, lanthanum, and didymium, but it contains a small amount of thoria, which makes it valuable for its present uses.

Uses.

For making the mantels of incandescent gas burners.

Occurrence.

It occurs as small crystals scattered through certain granites and gneisses. After the decay of the rocks the monazite is mechanically concentrated by water.

It was formerly mined in North Carolina[2] from small placer deposits.

It occurs also in Idaho.[3]

The largest monazite deposits known are in the beach sands of the coast of Brazil near Prado, 285 miles south of the city of Bahia. The sands are derived directly from the Cretaceous or Tertiary sediments that form the shore bluffs, but these sediments are derived from the older crystalline rocks.

Monazite sands have also been discovered on the beaches of New South Wales[4] and Queensland.[5]

[1]L. M. Dennis.—Monazite. Mineral Industry for 1897, VI, 487-494. New York, 1898.

O. A. Derby.—Notes on monazite. Amer. Jour. Sci., CLX, 217-221. New Haven, 1900.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Museum for 1899, 383-387. Washington, 1901.

H. B. C. Nitze.—Monazite. Sixteenth ann. rep. U. S. Geological Survey, pt. IV, 667-693. Washington, 1905. (Bibliography.)

C. H. Jouet.—Index to the literature of thorium, 1817-1902. Smithsonian Misc. Coll. Washington, 1903.

[2]H. B. C. Nitze.—Monazite and monazite deposits in North Carolina. Bul. 9, North Carolina Geological Survey. Winston, 1895.

C. A. Mezger.—The monazite districts of North and South Carolina. Trans. Amer. Inst. Min. Eng., XXV, 822-826. New York, 1896.

J. H. Pratt and D. B. Sterrett.—Monazite and monazite mining in the Carolinas. Trans. Amer. Inst. Min. Eng., XL, 313-340. New York, 1910.

D. B. Sterrett.—Monazite deposits of the Carolinas. Bul. 340D, U. S. Geological Survey, 44-57. Washington, 1908.

[3]F. C. Schrader.—An occurrence of monazite in northern Idaho. Bul. 430D, U. S. Geological Survey, 36-43. Washington, 1910.

[4]J. C. H. Mingaye.—Notes on the occurrence of monazite in the beach sands of the Richmond river, New South Wales. Records Geological Survey of New South Wales, VII, pt. III, 222-226. Sydney, 1903.

[5]B. Dunstan.—Monazite in Queensland. Pub. no. 196 of the Geological Survey of Queensland, 11-16. Brisbane, 1905.

The first shipments from Brazil sold for $425.00 a ton; in 1908 concentrated monazite sands averaging 90% monazite sold in New York at $240.00 per ton.

PRODUCTION OF MONAZITE IN THE U. S. IN 1908.

North Carolina	310,196 lbs	$37,224
South Carolina	112,450 lbs	13,494

PYRITE OR IRON PYRITES.[1]

(Other than that valuable for its gold or other metallic contents.)

Iron pyrites (FeS_2): iron 46.6, sulphur 53.4, is a hard brassy-yellow mineral, usually with a metallic lustre.

Uses.

Pyrites often carries gold, or other metals of value, but where these are absent it is often mined for the sulphur contained, for the manufacture of sulphuric acid. It was formerly used extensively for the manufacture of sulphur. It is valueless as an ore of iron on account of the sulphur present.

Used in the manufacture of wood pulp.[2]

Pyrites carrying less than 40% sulphur is not saleable.

Occurrence.

It usually occurs in veins and lenticular masses, but it is not limited to these modes of occurrence.

Some important pyrite deposits are bedded.

It is often associated with slates, schists, and gneisses in the eastern United States, but it also occurs associated with other country rocks.

It is common in many mining camps of the country.

Distribution.

Pyrite may occur in rocks of any geologic age; it is also widely distributed geographically.

The principal producing countries in the order of their output in 1907 were: France, Norway, United States,[4] Germany, Spain[5] and Italy.

[1]G. P. Merrill.—The nonmetallic minerals. Rep. U. S. National Museum, 1899, 190-193. Washington, 1901.

H. N. Stokes.—On pyrite and marcasite. Bul. 186, U. S. Geological Survey. Washington, 1901.

[2]Herman Frasch.—Brimstone versus pyrite for wood-pulp manufacture. Engineering and Mining Journal, LXXX, 1165-1166. New York, 1905.

[3]A. M. Finlayson.—The pyritic deposits of Huelva, Spain. Economic Geology, V, 357-372; 403-437. 1910.

[4]R. P. Rothwell.—Mineral Resources of the United States for 1886, 650-675. Washington, 1887.

H. J. Davis.—Mineral Resources of the United States for 1885, 506-517. Washington, 1886.

E. W. Parker.—Seventeenth ann. rep. U. S. Geological Survey for 1895-96, pt. III (continued), 973-977. Washington, 1896.

Pyrite in the United States.

Pyrite occurs in nearly every state. It is mined for the production of sulphuric acid only in the region along the Atlantic coast.[5]

Virginia[6] Louisa and Prince William counties.

Massachusetts: the Davis mines in Franklin county supplies 90% of ore mined in this country.

Deposits occur also in Vermont, New York, Pennsylvania, North Carolina,[7] South Carolina, Tennessee, Arkansas, and California.

The principal pyrite producing states in 1908 were: Virginia, Massachusetts, California, Alabama, and Georgia.

PRODUCTION AND IMPORTS OF PYRITES IN THE UNITED STATES.

	Production		Imports
Year	Tons	Value	Tons
1895	101,495	$322,845	213,287
1900	229,000	749,991	361,500
1905	283,500	938,492	572,500
1908	249,000	857,113	749,000

[5]A. F. Wendt.—The pyrites deposits of the Alleghanies. School of Mines Quarterly, VII, 154-188, 218-235, 301-323. New York, 1886.

[6]W. H. Adams.—The pyrites deposits of Louisa county, Virginia. Trans. Amer. Inst. Min. Eng., XII, 527-535. New York, 1884.

[7]A. Winslow.—Pyrites deposits of North Carolina. Ann. rep. N. C. Agr. Exp. Sta. Raleigh, 1886.

FLUORITE OR FLUORSPAR.[1]

Fluorspar is calcium fluoride (CaF_2): (fluorine 48.9, calcium 51.1); it is a transparent or semi-transparent mineral; is brittle and easily scratched with a knife. Yellow, white, purple, or light green are its most common colors. The colors are often banded. It is usually found crystallized in cubes.

Uses.

When massive, fluorspar takes a fine polish, and is made into vases and other such ornaments.

The principal uses are:

For the manufacture of hydrofluoric acid for which only the purest qualities are used.

As a flux in the reduction of various ores.

It is especially important in the basic open-hearth process of steel manufacture where phosphorus and sulphur are removed by it.

In the manufacture of opalescent glass.

Enameling.

Occurrence.

Fluorite is limited to no particular kind of rock or mode of occurence; it occurs sometimes in beds, but usually as a veinstone of various ores in gneiss, slate, limestone, and sandstone. It frequently constitutes the entire mineral of a vein.

Fluorite occurs in many localities in the United States, but all that is produced comes from the Illinois-Kentucky localities.

Illinois[2]: the production of the state in 1908 was 31,727 tons, worth $172,838.

In Harden county in southern Illinois are extensive deposits of fluorite, associated with galena and blende in veins following fault lines in Carboniferous rocks.

Kentucky[3]: the production of the state in 1908 was 6,323 tons, worth $48,642.

[1]S. F. Emmons.—Fluorspar—deposits of southern Illinois. Trans. Amer. Inst. Min. Eng., XXI, 31-53. New York, 1893.

W. M. Eggleston.—The occurrence and commercial uses of fluorspar. Trans. Brit. Inst. Min. Eng., XXXV, pt. 2, 271-284. 1908.

[2]H. F. Bain.—Fluorspar deposits of southern Illinois. Bul. 225, U. S. Geological Survey, 505-511. Washington, 1904.

[3]E. O. Ulrich and W. S. Tangier Smith.—The lead, zinc, and fluorspar deposits of western Kentucky. Professional Paper 36, U. S. Geological Survey. Washington, 1905.

F. Julius Fohs.—The fluorspar deposits of Kentucky. Bul. 9, Kentucky Geological Survey. Lexington, 1909.

F. Julius Fohs.—The fluorspar, lead, and zinc deposits of western Kentucky. Economic Geology, V, 377-386. 1910.

Crittenden county in western Kentucky, south of the Illinois deposits, has large vein deposits, similar to those of Illinois.

The fluorite of the Illinois-Kentucky localities is thought by Emmons to be derived from the associated limestones.

Colorado is the only other state producing a considerable amount of fluorspar. The output in 1907 was 3,300 tons.

The mineral occurs in veins cutting granites and gneisses of pre-Cambrian age.[4]

[4]E. F. Burchard.—Fluorspar and cryolite. Mineral Resources of the U. S. for 1908, pt. II, 607-620. Washington, 1909. (Bibliography.)

NATURAL FERTILIZERS.[1]

Mineral Phosphates.[2]

APATITE.

The mineral phosphate, apatite ($3Ca_5P_2O_8 + CaF_2$) contains theoretically 42.3% phosphoric acid, 49.95% lime, and 7.75% calcium fluoride. Analyses show from 34 to 44% phosphoric acid.

It is found in crystalline and stratified rocks, but more plentifully in the former, especially in metamorphic limestone, in gneiss and schist.

Apatite is both massive and crystalline; some crystals are large enough to weigh 550 lbs.

The Canadian deposits[3] in Quebec and Ontario are in metamorphosed Laurentian rocks, usually associated with limestone.

They are in the form of veins, beds and irregular pockets from an inch to many feet thick.

Methods of mining and preparing.

Apatite lands are generally of little value for other purposes.

Effect of Florida phosphate discoveries on the Canadian apatite business.

PHOSPHORITE.

Phosphorite includes the vitreous, earthy, scaly, and fibrous forms of apatite.

It is found in Spain, Germany, and near Bordeaux, France, in veins and pockets. It is not found in the United States.

Rock Phosphates.[4]

Rock phosphates have not the structure or composition of a definite mineral

[1]The American Fertilizer, an illustrated magazine, published at Philadelphia.

G. P. Merrill.—The nonmetallic minerals. Rep. U. S. Nat. Mus. for 1899, 356-382. Washington, 1901. (Bibliography.)

[2]R. A. F. Penrose Jr.—Nature and origin of deposits of phosphate of lime. Bul. 46, U. S. Geological Survey. Washington, 1888. (This work contains a full bibliography of the subject up to the date of its publication.)

Francis Wyatt.—The phosphates of America. Fifth edition. New York, 1894.

C. C. Hoyer Millar.—Florida, South Carolina, and Canadian phosphates. London, 1892.

H. W. Wiley.—Mineral phosphates as fertilizers. Year-book U. S. Dept. Agriculture, pp. 177-192. Washington, 1895.

[3]J. F. Torrance.—Report on apatite deposits, Ottawa county, Quebec. Geol. Survey of Canada, 1884, J. Montreal, 1885.

[4]David Levat.—Etude sur l'industrie des phosphates et superphosphates. Ann. des Mines, 9me sér. VII, 5-260. Paris, 1895.

NODULAR PHOSPHATES.

The nodules are worn and irregular in shape, varying in weight from a few grains to several tons.

Formed by erosion of the marl beds and the concentration of the contained nodules.[5]

Artificial concentration at Belgarde.

Local accumulations or concentrations on land or in stream beds in South Carolina.

Worked in South Carolina only since 1868.

Dredged from streams or dug from open pits.

Burning of from 12 to 18% of water.

Florida has the phosphates in Eocene, Miocene, and recent deposits.[6]

As pockets in limestone.

Prospected by shafts and bore holes.

Local accumulations of loose nodules and boulders from disintegrated rock often cover several acres; 5,000 acres, purchased at $100 per acre, had 80 feet of workable phosphate rock over the entire area.

Mined in open cuts and pits.

As pebbles in existing streams; dredged out.

Tennessee.[7]

The brown phosphates are of Devonian age.

Horizontally bedded Ordovician and Carboniferous rocks are locally rich in phosphates.

Form of the outcrop; method of tracing the beds.

Arkansas has beds from a few inches to 6 feet thick composed of phosphate nodules in Paleozoic conglomeratic sandstones.[7a]

[5]A. Carnot.— . . . Remarques sur le gisement et le mode de formation de ces phosphates. Ann. des Mines, 9me sér., X, 137-231. Paris, 1896.

[6]W. B. Phillips.—Florida land pebble phosphate. Engineering and Mining Journal, LXIX, 201-202. New York, 1900.

E. W. Codington.—The Florida pebble phosphates. Trans. Amer. Inst. Min. Eng., XXV, 423-431. New York, 1896

[7]T. C. Meadows and L. Brown. The phosphates of Tennessee. Trans. Amer. Inst. Min. Eng., XXIV, 582-594. New York, 1895.

C. W. Hayes.—The white phosphates of Tennessee. Trans. Amer. Inst. Min. Eng., XXV, 19-28. 1896.

C. W. Hayes.—The Tennessee phosphates. Seventeenth ann. rep. U. S. Geological Survey, pt. II, 513-550. Washington, 1896.

J. M. Safford.—A new and important source of phosphate rock in Tennessee. Amer. Geologist, XVIII, 261-264. Minneapolis, 1896.

H. D. Ruhm.—Phosphate mining in Tennessee. Engineering and Mining Journal, LXXXIII, 522-526. New York, 1907.

J. M. Safford.—Horizons of phosphate rock in Tennessee. Bul. Geol. Soc. Amer., XIII, 14-15. Rochester, 1902.

[7a]J. C. Branner and J. F. Newsom.—The phosphate rocks of Arkansas. Bul. 74, Ark. Agr. Exp. Sta. Little Rock, 1902.

The phosphates of Utah,[8] Wyoming[8] and Idaho.[8]

The phosphates occur in several beds ranging from a few inches to 10 feet in thickness in Upper Carboniferous shales and limestones.

GUANO.

Guano is bone phosphate of lime, with hydrous phosphates and impurities.

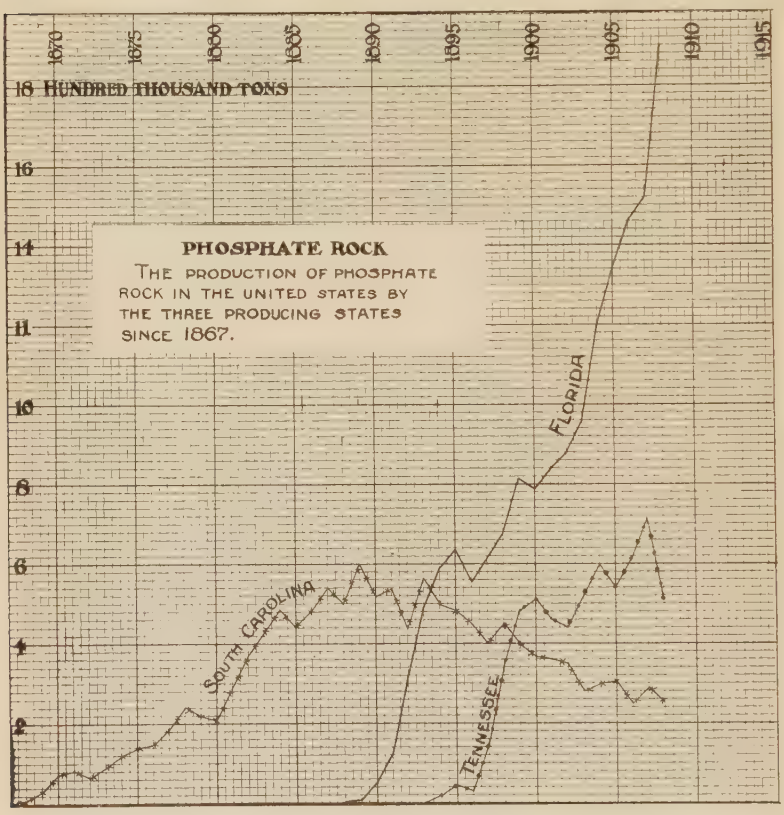

Fig. 117.

The principal fertilizer works are at Boston, New York, Philadelphia, Baltimore, and Charleston.

[8]W. H. Waggaman.—A review of the phosphate fields of Idaho, Utah, and Wyoming. Bul. 69, Bureau of Soils. U. S. Dept. Agr. Washington, 1910.

H. S. Gale and R. W. Richards.—Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah. Bul. 430H, U. S. Geological Survey. Washington, 1910.

Deposits formed of the excrement of birds.[10]

Considerable beds on the islands off the coast of Peru.[11]

Owing to the aridity of the climate these deposits are not washed off.

Irregular form of the deposits owing to the surfaces on which they are made.

Ammonia and phosphorus the fertilizing ingredients.

Beds not extensive, and the supply is limited.

Proposed protection to the guano-producing birds.

GREENSAND MARLS.[12]

Greensands, or glauconite marls, are soft sedimentary deposits whose fertilizing ingredients are phosphoric acid potash, and lime. They occur in regular approximately horizontal beds, in Cretaceous rocks of New Jersey,[13] in the Tertiary of North Carolina, in the Eocene Tertiary of South Carolina, in the Cretaceous of Arkansas, and probably throughout the Cretaceous and Tertiary areas of the south and southwest.

Origin of the lake marls of Indiana[14] and Michigan.

Value of marls to the agriculture of New Jersey.

1,080,000 tons dug in New Jersey in 1882.

Method of using.

Their value is low and they will not bear much transportation.

Methods of treatment of greensands at Belgarde, France, to save phosphatic nodules.

GYPSUM.

Gypsum, or "land plaster," occurs in regular stratified beds.

It is quarried and crushed before it is put on the market.

Extensively quarried in New York, Nova Scotia, Sandusky, Ohio, Michigan, and Kansas.

In California there are pockety deposits in the semi-arid portions of the San Joaquin valley probably deposited by ancient springs.

New Mexico has extensive dunes of gypsum sands on the Tularosa desert.[15]

Utah has similar deposits.[15]

[10]R. E. Coker.—Regarding the future of the guano industry and the guano-producing birds of Peru. Science, new. ser., XXVIII, 58-64. New York, 1908.

[11]W. J. Wharton.—Notes on Clipperton Atoll. Quarterly Journal Geol. Soc., LIV, 228-229. London, 1898.

J. D. Hague.—On phosphatic guano islands of the Pacific Ocean. Amer. Journal Sci., LXXXIV, 224-243. New Haven, 1862.

A. J. Duffield.—Peru in the guano age. London, 1877.

[12]Charles A. Davis.—A contribution to the natural history of marl. Journal of Geology, VIII, 485-497. Chicago, 1900. A second contribution to the natural history of marl. IX, 491-506. Chicago, 1901.

[13]W. B. Clark.—Origin and classification of the greensands of New Jersey. Journal of Geology, II, 161-177. Chicago, 1894.

[14]W. S. Blatchley and G. H. Ashley.—The lakes of northern Indiana and their associated marl deposits. 25th ann. rep. Dept. of Geol. and Nat. History of Indiana, 31-321. Indianapolis, 1901.

[15]E. D. Johnson.—The white sands of New Mexico. Out West, Oct., 1903, pp. 385-387.

PRECIOUS STONES.[1]

Precious stones are no particular kind of stones; the value of those used as such is a matter of fancy and fashion.

Interest in precious stones; amount invested in precious stones by individuals in the United States.

The essential qualities of precious stones are hardness, beauty of color, and rarity.

Examples: diamond, h. 10; oriental ruby, h. 9; oriental emerald, h. 9.

DIAMONDS.

Uses.

Brilliants.

Glass cutting.

Polishing powder.

Diamond drills of bort or *carbonado*.

Occurrence and Origin.[2]

Diamonds are crystals of pure carbon.

They are found in placers, in conglomerates, and in rocks in place.

Theory of their plant origin; graphite found in the diamond bearing rocks of Brazil.

Theory of their igneous or metamorphic origin.

Possible gaseous origin of the carbon.

Common sizes; sizes of famous diamonds.

Artificial production of diamonds.[3]

[1]E. W. Streeter.—Precious stones and gems; their history; sources and characteristics. Fifth ed. London, 1892.

George F. Kunz.—Gems and precious stones of North America. New York, 1892.

George F. Kunz.—Precious stones. Twentieth ann. rep. U. S. Geological Sur., pt. VI (continued), 557-602. Washington, 1899.

G. F. Kunz.—Gems, jewelers' materials and ornamental stones of California. Bul. 37, Cal. State Min. Bureau. Sacramento, 1905.

O. C. Farrington.—Gems and gem minerals. XII + 229 pp. 4 q. ill. Chicago, 1903.

D. B. Sterrett.—Precious stones. Mineral Resources of the United States for 1908, II, 805-859. Washington, 1909.

[2]O. A. Derby.—Brazilian evidence on the genesis of the diamond. Journal Geology VI, 121-146. Chicago, 1898.

Wm. Crookes.—Diamonds. Nature, LVI, 325-331. London, 1897.

H. W. Turner.—The occurrence and origin of diamonds in California. Amer. Geol., XXIII, 182-191. Minneapolis, 1899.

W. H. Hudleston.—On a recent hypothesis with respect to the diamond rock of South Africa. Mineralogical Mag., V, 199-210. Philadelphia, 1884.

[3]On the artificial production of the diamond. Amer. Jour. Sci., CLIII, 243. New Haven, 1897.

Annales de Chimie, 7me ser., VIII, 466. 1896.

Comptes Rendus CXXIII, 206-210, 277. Paris, 1896.

Diamonds found in commercial quantities only in India, Borneo, Brazil, South Africa, New South Wales,[4] and Arkansas.

Only a few have been found in the United States outside of Arkansas.[5]

India.[6]

Those of India are the oldest known diamond mines. They supplied Europe until the discovery of diamonds in Brazil, about 1729.

The mines are all south of the Ganges.

The most famous mines are those of Panna and of Parteal, near Golconda, the old diamond market.

The stones are found in two deposits; (1) in a conglomerate at the base of the pre-Cambrian Karnul beds; (2) in recent stream deposits derived in part from the Karnul conglomerate.

The Karnul conglomerates and their diamonds are supposed to be derived from earlier rocks. Indian diamonds are not known to have been found in their original matrix.

Crude methods of working the conglomerates.

Relations of structure to the occurrence of diamonds.

Possibilities of improved methods of work.

Borneo.

Diamonds have been found in several islands of Oceanica, but Borneo has been the only one to produce them in quantity.

They are found there mostly in river gravels overlying Tertiary, and in smaller quantities in rocks in place. The rocks of the region are schists, granites, and other igneous rocks.

1836 to 1848 yield averaged $36,179 worth per year.

1876 to 1880 yield averaged $63,750 worth per year.

Brazil.[7]

Diamonds were discovered in the gold mines in 1727 or 1728.

Artificial diamonds. Jour. Franklin Institute. CXLVI, 236-237. Philadelphia, 1898.

[4]E. F. Pittmann.—The mineral resources of New South Wales, 373-397. Sydney, 1901.

[5]W. Tassin.—Descriptive catalogue of the collections of gems in the U. S. Nat. Museum. Rep. U. S. Nat. Mus. for 1900, pp. 473-670. Washington, 1902. Illustrated. (Bibliography.)

G. F. Kunz and H. S. Washington.—Diamonds in Arkansas. Trans. Amer. Inst. Min. Eng., XXXIX, 169-176. New York, 1909.

J. C. Branner.—Some facts and corrections regarding the diamond region of Arkansas. Engineering and Mining Journal. LXXXVII, 371-2. New York, 1909.

[6]R. F. Burton.—The diamond in India. Quar. Jour. Sci. XIII, 351-360. London, 1876.

V. Ball.—A manual of the geology of India, pt. III, economic geology, pp. 1-50. Calcutta, 1881.

V. Ball.—On the mode of occurrence and distribution of diamonds in India. Jour. Roy. Geol. Soc. Ireland VI New Ser. 10:48. Edinburgh, 1886.

[7]John Mawe.—Travels in the interior of Brazil. Philadelphia, 1816.

H. Jacobs and N. Chatrian.—Monographie du diamant. Paris, 1880.

M. E. Boutan.—Encyclopédie chimique de M. Fremy. II. Métalloides Diamant. Paris, 1886.

Brazil was then a Portuguese colony; the diamond lands were appropriated by the crown and worked by contractors and later by the royal treasury.

Total production of Brazilian diamonds by the best possible estimates from 1728 to 1885, 12,000,000 carats, or about two and a half tons, worth about $100,000,000.

Geographically the diamonds are confined to limited areas in the states of Bahia, Minas Geraes, and Matto Grosso.

Geologically they are found chiefly and almost exclusively in the gravels of ancient or modern streams.

Methods of working on a small scale.

Heavy work of turning the streams.

Ancient methods used for dams, flumes, and cleaning up.

The visit of John Mawe in 1809.

Possibilities of improved methods of work.

Camara's use of machinery; why it failed.

Condition of the common roads.

Character of the labor available.

Black diamonds or *carbonados* are found only in the state of Bahia.

They occur in pinkish quartzites and in the soils derived therefrom.[8]

Their uses in diamond drills.

Demand produced by boring machines.

British Guiana.

Magaruni river district produced $50,000 worth of diamonds in 1902.

South Africa.[9]

Effect of the discovery of African diamonds in 1865 upon the other diamond mines.

Geology: peridotite dike in Carboniferous black shales.[10]

[8]J. C. Branner.—The economic geology of the diamond-bearing highlands of the interior of the state of Bahia, Brazil. Engineering and Mining Journal, LXXXVII, 981-986, 1029-1033. New York, 1909.

[9]G. G. Hubbard.—Africa since 1888. Nat. Geogr. Mag., VII, 161-162. May, 1896.

T. Reunert.—Diamonds and gold in South Africa. Johannesburg, 1893.

Wm. Crookes.—The diamond mines of Kimberly. Nature, LV, 519-523. London, 1897.

H. Jacobs et N. Chatrian.—Monographie du diamant. Paris, 1880.

G. F. Williams.—The diamond mines of South Africa. Trans. Amer. Inst. Min. Eng., XV, 392-417. New York, 1887.

A. A. Julian.—A bibliography of the diamond fields of South Africa. Economic Geology, IV, 453-469. Aug., 1909; and V, 64-65. January, 1910.

[10]T. G. Bonney.—The parent-rock of the South African diamond. Nature LX, 620-621. London, 1899.

F. W. Voit.—Kimberlite rock and the origin of diamonds. Engineering and Mining Journal, LXXXVII, 789-791. April 17, 1909.

H. S. Harger.—The diamond pipes and fissures of South Africa. Trans. Geol. Soc. S. Africa. VIII, 110-134. Johannesburg, 1906.

Supposed influence of the shales on the formation of the diamonds.
Effect of depth on African diamonds.
Cracking after removal.
The use of machinery favored by the local nature of the deposits.[11]

[11]R. A. F. Penrose, Jr.—The Premier diamond mine, Transvaal, South Africa. Economic Geology II, 275-284. 1907.
F. H. Hatch.—A description of the big diamond recently found in the Premier mine, Transvaal. Geological Magazine, new series, II, 170-172. London, 1905.

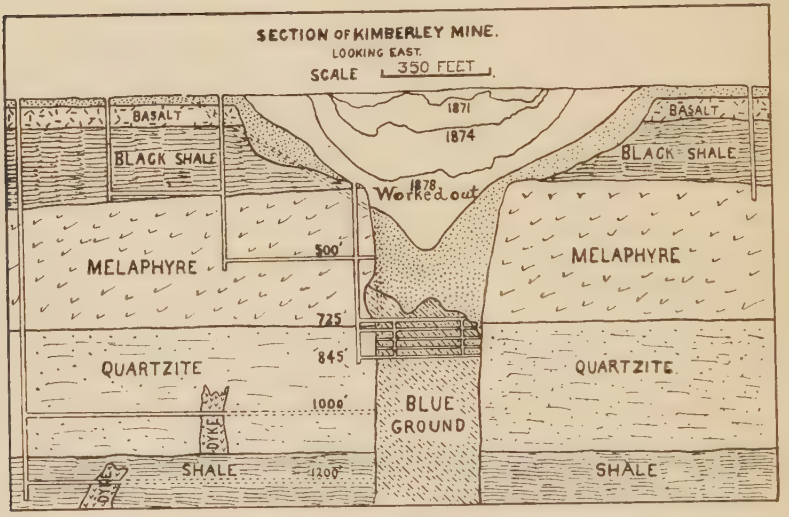

Fig. 118.—Vertical section through the Kimberly diamond mine, South Africa. (Reunert.)

OTHER PRECIOUS STONES.

Corundum.[12]

(Oxide of aluminum (Al_2O_3): oxygen 47.1, aluminum 52.9.)

The varieties of corundum differ chiefly in colors due to small amounts of the metallic oxides. These varieties are:

Sapphire,[13] blue, from Burma,[14] and Queensland.[15]

Oriental emerald is a green sapphire.[16]

Oriental ruby is red.

Artificially made rubies.[17]

Topaz, yellow.[18]

Oriental amethyst, purple.

These stones come chiefly from Burma, Ceylon and Siam, where they occur as crystals in limestone, or derived from it by disintegration.

Turquoise.

Is a hydrous phosphate of aluminum containing water 20.6, alumina 46.8, and phosphorous pentoxide 32.6. It usually contains some copper and iron.

Color, from sky-blue to greenish-gray.

Occurrence.[19]

Oriental turquoise is found in thin seams in igneous rock in Persia.

Egyptian turquoise comes from Carboniferous sandstones and with age changes from blue to green.

American turquoise is found in three states.

At Los Cerrillos and Burro Mountain, New Mexico.[20]

[12]J. H. Pratt.—The occurrence and distribution of corundum in the United States. Bul. 180 U. S. Geological Survey. Washington, 1901.

[13]W. H. Weed.—Yogo sapphire mines (Fergus county, Montana). 20th Ann. Rep. U. S. Geological Survey, part III, 454-459. Washington, 1900.

[14]C. B. Brown and J. W. Judd.—The rubies of Burma and associated minerals. Philosophical Trans. Roy. Soc. CLXXXVII, 151-228. London, 1896.

[15]B. Dunstan.—The sapphire fields of Anakie. Queensland, 1902.

[16]V. Ball.—On the newly discovered sapphire mines in the Himalayas. Jour. Roy. Geol. Soc. Ireland. VII, 49-51. 1885.

[17]M. A. Verneuil.—La reproduction artificielle du rubis par fusion. Ann. de Chimie et de Phys. 8me sér. II. Paris, 1904.

[18]O. A. Derby.—On the mode of occurrence of topaz near Ouro Preto, Brazil. Amer. Jour. Sci., CLXI, 25-34. New Haven, 1901.

[19]T. Barron.—The topography and geology of the Sinai Peninsula. 209-212. Cairo, 1907.

[20]G. D. Reid.—The Burro mountain turquoise district. Engineering and Mining Journal, LXXV, 786. New York, 1903.

E. R. Zalinski.—Turquoise in the Burro Mts., New Mexico. Economic Geology, II, 464-492. 1907.

D. W. Johnson.—The geology of the Cerillos Hill, New Mexico. School of Mines Quarterly, XXIV, 456-500. New York, 1903.

In Cochise county, Arizona.[21]
In the western part of Kern county, California.

Garnet.

The precious garnet is almandite (silica 36.2, alumina 20.5, iron protoxide 43.3) and pyrope (silica 44.8, alumina 25.4, magnesia 29.8).
Several minerals are included under this head; the finest of them are from India; fire pyrope from the Kimberly diamond mines, South Africa.

Jade.[22]

Nephrite, a variety of amphibole with little or no aluminum.
Jadeite.

Beryl.

Aqua-marine, emerald, and oriental cat's-eyes are varieties of beryl. The former occur as isolated crystals and in geodes in clay slate in Colombia; in Brazil, Hindostan, Ceylon, and Siberia.

Tourmaline.

Rubellite is a pink variety of tourmaline; indicolite is a blue variety. Brazilian emerald is a green variety of tourmaline.

Quartz.

Many beautiful gems made from quartz and from various minerals belonging to the quartz group. Extensive use of common clear quartz and gold quartz.
Under crystalline quartz belong amethyst, cairngorm, cat's-eye, false topaz, and many others.
Under cryptocrystalline quartz are agate from southern Brazil,[24] moss agate, chalcedony, carnelian, jasper, onyx (used for cameos), silicified wood or wood-agate.[25]

Opal is silica with varying amount of water.[26]
Fire opal[27] from Mexico and New South Wales.[28]

[21]A. B. Frenzel.—A turquoise deposit in Mohave county, Arizona. Engineering and Mining Journal, LXVI, 697. New York, 1898.

[22]S. E. Easter.—Jade. Nat. Geographic Magazine, XIV, 9-17. Washington, 1903.

[24]H. H. Smith.—Amer. Naturalist, XVII, 1012-1013. Philadelphia, 1883.
On the formation of agate, see Bischof's Chemical geology, I, 53-54. London, 1854.

[25]Angelo Heilprin.—The stone forest of Florssant. Pop. Sci. Monthly, XLIX, 479-484. New York, 1896.

[26]R. M. Macdonald.—The opal formations of Australia. Scot. Geographical Mag. XX, 253-261. Edinburgh, 1904.
C. F. V. Jackson.—The opal-mining industry and the distribution of opal deposits in Queensland. Geol. Sur. Rep. 177. Brisbane, 1902.

[27]G. F. Kunz.—Gems and precious stones of Mexico. Trans. Amer. Inst. Min. Eng. XXXII, 55-93. New York, 1902.

[28]E. P. Pittmann.—The mineral resources of New South Wales, 398-405. Sydney, 1901.

Pearls.[29]

Pearls are not stones, although grouped with precious stones commercially. "Pearls are lustrous concretions, consisting essentially of carbonate of lime interstratified with animal membrane, found in the shells of certain mollusks." Kunz.[30]

Probably formed about foreign bodies in the mantle.

Pearls of commerce are from bivalve shells, most of them from Meleagrina, the pearl oyster. They are furnished also by some fresh-water shells, Unio, Anadon, etc., in Wisconsin and throughout the Mississippi valley. La Paz, Lower California, is the center of the pearl-fishery in America.[31]

Venezuela.[32]

Ceylon.[33]

[29]G. F. Kunz.—On pearls . . . . as ornaments, etc. Bul. U. S. Fish Com. XIII, 439-454. Washington, 1907.

[30]H. L. Jameson.—On the origin of pearls. Proc. Zool. Soc. I, 140-166. London, 1902.

[31]George F. Kunz.—Gems and precious stones of North America. New York, 1892.

[32]Pearl fisheries in Venezuela.—Engineering and Mining Journal, LXXII, 37. New York, 1901.

[33]W. A. Herdman.—Report to the Governor of Ceylon on the pearl-fishing industry of the gulf of Manaar. Roy. Soc. London, 1905.

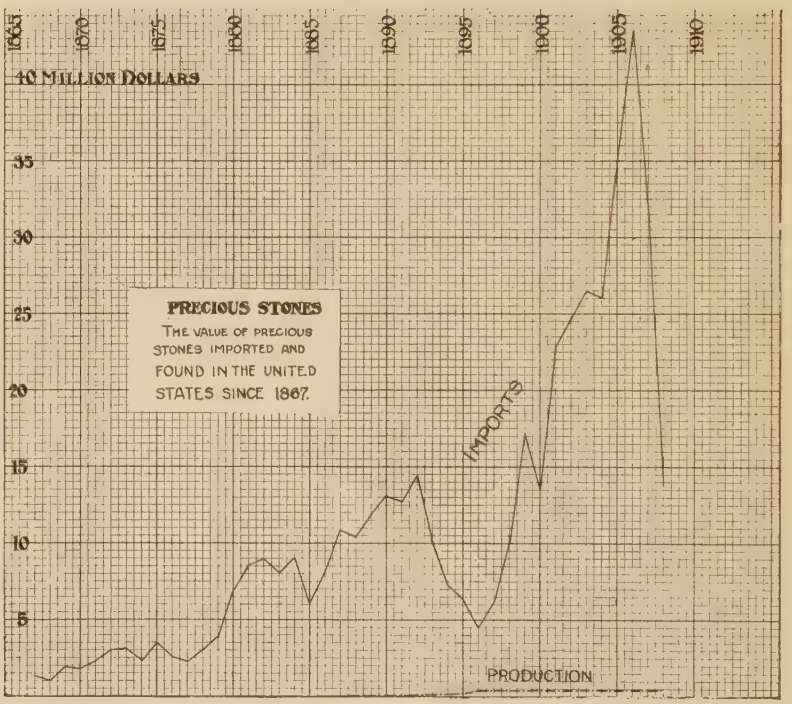
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
40 MILLION DOLLARS
35
30
25
20
15
10
5
PRECIOUS STONES
THE VALUE OF PRECIOUS STONES IMPORTED AND FOUND IN THE UNITED STATES SINCE 1867.
IMPORTS
PRODUCTION

Fig. 119.

SOILS.[1]

Residuary Soils.

Decay of rocks in place.[2]

Varying character and fertility according to the rock matrix.

Lake and sea-bottom soils of recent date.

The Tertiary and Pleistocene of the Gulf States.

Origin of these sediments.

The lake bottoms of Pleistocene times.

The San Joaquin and Santa Clara valleys.

Adobes from three sources:

1. Rocks decayed in place.
2. Washed down from such decayed beds.
3. Wind-blown.[3]

Talus Soils.

Talus from cliff and rock slopes.

Soil by decay of rock fragments.

Alluvial Soils.

Silts deposited by water.

Origin of the alluvial silts.

Fertility of river bottoms due partly to organic matter in the silts.

Silting up of deltas and overflow deposits.

[1]The soils of Tennessee. Bul. Agr. Expr. Station of Tenn., Sept. 1897, X, no. 3. Knoxville, 1897.

F. H. King.—The soil: its nature, relations, etc. New York, 1895.

N. S. Shaler.—The origin and nature of soils. Twelfth ann. rep. U. S. Geological Survey, pp. 213-345. Washington, 1892.

E. A. Smith.—A general discussion of the composition, mode of formation, and properties of soils. Geol. Sur. of Alabama for 1881 and 1882, pp. 1-154. Montgomery, 1883.

E. W. Hilgard.—Soils. New York, 1906.

M. Whitney.—Field operations of the divisions of soils, 1900. U. S. Dept. Agri., 1900. Second rep. Washington, 1901.

F. K. Cameron and J. M. Bell.—The mineral constituents of the soil solution. U. S. Dept. Agri. Bul. 30. Washington, 1905.

[2]T. L. Watson.—Weathering of granitic rocks of Georgia. Bul. Geol. Soc. Amer. XII, 93-108. Rochester, 1901.

E. W. Hilgard.—Some peculiarities of rock weathering and soil formation in the arid and humid regions. Amer. Jour. Sci. CLXXI, 261-269. New Haven, 1906.

[3]I. C. Russell.—Subaërial deposits of the arid regions of North America. Geol. Magazine, VI, 289-295, 342-350. London, 1889.

Glacial Soils.[4]

Origin of the glacial drift.

Variety and mingling of its ingredients, and the effect upon soil fertility. Illustrated by contrasts in Ohio, Indiana, Kentucky, and Wisconsin.

Glacio-alluvial Soils.

Silts draining from glaciers.

Modifications of Soils.

After formation soils are variously modified by changes of tepemerature, by rain, plants, and animals.

Leaching action of acidulated waters; the origin of "buckshot" soils.

Wind-blown accumulations as illustrated by the loess deposits of China and of the Mississippi valley;[5] adobe of the deserts.

Accumulations of volcanic ashes that decay rapidly, as illustrated in Bolivia, Italy, and other regions about volcanoes.

Swamps, marshes, peat-bogs, prairies.[6]

The work of burrowing animals, gophers, squirrels, ants,[7] and earthworms and their influence on soils.

The waste of soils by washing.[8]

Alkali soils.

Origin of the alkali.[9]

The fertility of soils.[10]

The exhaustion of soils.[11]

[4]Frank Leverett.—Soils of Illinois. Extract from final report Illinois Board of World's Fair Com. Springfield, 1895.

[5]B. Shimek.—The genesis of loess, a problem in plant ecology. Proc. Ia. Acad. Sci. XV, 57-75. 1909.

[6]Leo Lesquereux.—On the origin and formation of prairies. Economical Geol. of Illinois, I, 178-190. Springfield, 1882.

[7]J. C. Branner.—Decomposition of rocks in Brazil. Bul. Geol. Soc. of America, VII, 295-304. Rochester, 1896.

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N. S. Shaler.—The economic aspects of soil erosion. National Geographic Magazine, VII, 328-338. Washington, 1896.

[9]E. W. Hilgard.—A report on the relations of soil to climate. Bul. 3, Weather Bureau, U. S. Dept. of Agriculture. Washington, 1892.

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[10]E. W. Hilgard.—The chemistry of soils as related to crop production. Science, New Ser., XVIII, 755-760. New York, 1903.

M. Whitney and F. K. Cameron.—The chemistry of the soil as related to crop production. Bureau of Soils. Bul. 22, Washington, 1903.

[11]M. Whitney.—Exhaustion and abandonment of soils. Rep. 70, U. S. Dept. Agri., Washington, 1901.

WATER.[1]

A country's water supply is derived: (1) directly from rain; (2) from lakes; (3) from rivers; (4) from springs; (5) from wells, ordinary and artesian wells.

Effect of andesite and other porous rocks on water supply.

Lakes: Size, depth, character, and distribution of lakes is largely controlled by geology.

Rivers: Location and character are determined by the geologic structure of the region.

Effect of rapids and water-falls; sources of water power; detriment to navigation.

Utilization of muddy water after filtering. Effect of alum, acids, alkalies, heat, cold, etc., upon muddy waters.

Underground Waters.[2]

Relation of underground waters to geologic structure.

Springs: Location, character, and size are determined by geologic and structural relations of the rocks.

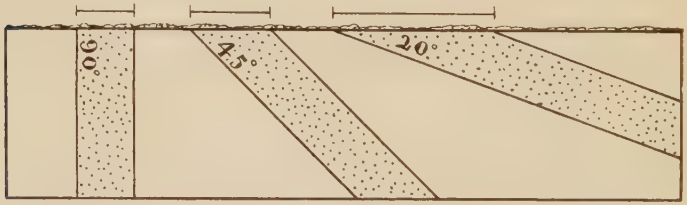

Fig. 120.—Diagram illustrating the area of an outcrop varying with the angle of the dip.

[1]Water supply papers of the U. S. Geological Survey, published at Washington since 1897.

Charles E. De Rance.—The water supply of England and Wales. London, 1882.

J. C. Branner.—The mineral waters of Arkansas. Ann. rep. Geol. Survey of Arkansas for 1891, I. Little Rock, 1892.

Paul Schweitzer.—The mineral waters of Missouri. Ann. rep. Geol. Survey of Missouri, 1890-92, III. Jefferson City, 1892.

Water supplies and inland waters of Massachusetts. Part I, rep. on water supply and sewerage, 1887-90. By the State Board of Health, Boston, 1890.

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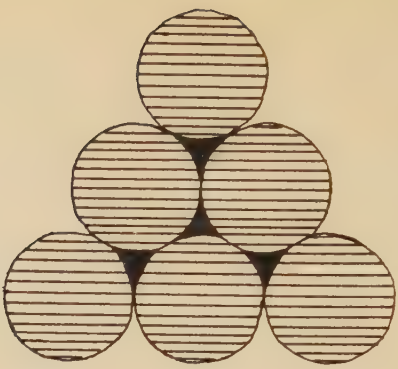

Fig. 121.—Diagram illustrating the interstices left between pebbles.

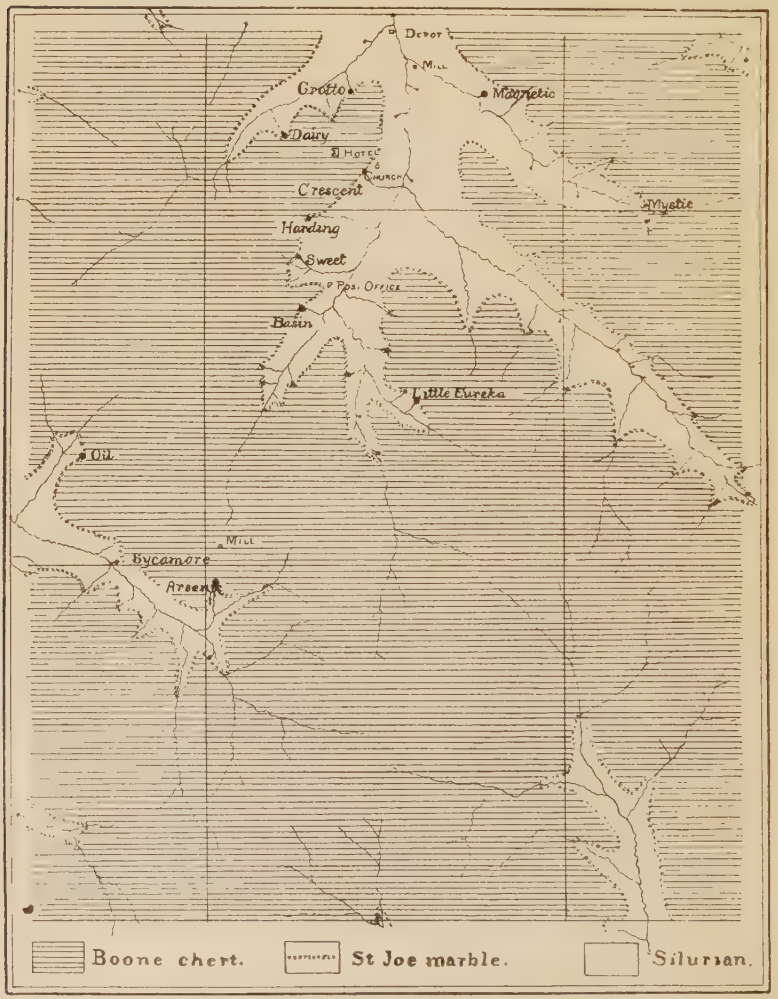

Fig. 122.—Geological map of the region about Eureka Springs, Arkansas, showing the emergence of springs at a constant geologic horizon.

Springs are of all sizes, from the smallest trickling streams to those of great volume. Mammoth Spring of Arkansas discharges 9,000 barrels per minute.

Underground streams;[3] traced by the use of fluoresceine.[4]

Cities and towns often owe their location to springs.

All spring waters contain more or less mineral matter in solution.

Some of them are used for medicinal purposes.[5]

Hard water of limestone regions.

Soft water of granite and sandstone regions.

Mineral springs as health and pleasure resorts.

The temperatures of spring waters vary from extremely cold to boiling hot.

Hot springs.

Geysers.

Common wells: Wells, except for large cities, are the chief source of water supply for domestic purposes.

Ordinary wells, especially in cities, are liable to surface contamination and cannot furnish a great volume of water.

Why some wells yield soft water and others near by yield hard water.

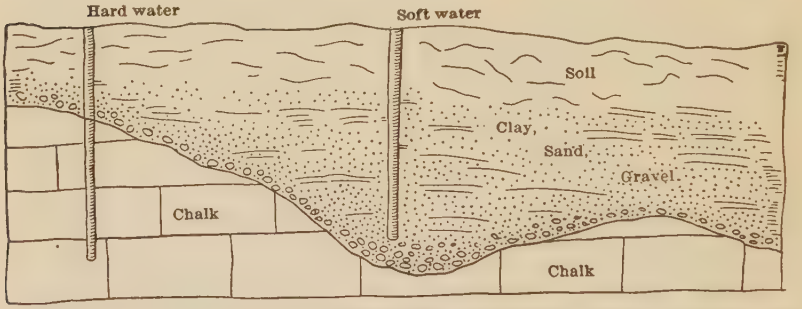

Fig. 123.—Vertical section in the chalk region of southwest Arkansas, showing why the waters of some of the wells are hard while others are soft.

Why water is not always found at the same level in regions covered by glacial drift.

Relations of well waters to structural geology.

[3] C. S. Slichter.—(The motions of underground waters.) Water supply and irrigation paper no. 67. U. S. Geological Survey, Washington, 1902. Also paper no. 140, Washington, 1905.

[4] R. B. Dole.—The use of fluorescein in the study of underground waters. Water supply and irrigation papers no. 160, pp. 73-85. U. S. Geological Survey, Washington, 1906.

[5] A. C. Peale.—The natural mineral waters of the United States. Fourteenth ann. rep. U. S. Geological Survey, pt. II, 49-88. Washington, 1894.

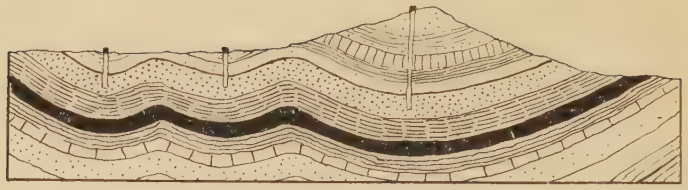

Fig. 124.—Section showing the location for wells with reference to geologic structure.

Artesian wells[6] are usually deep wells that flow at the surface, or in which the water rises even if it does not overflow.

Conditions favorable for artesian wells: a porous stratum, below an impervious stratum, with an exposed edge higher than the mouth of the well; no outlet lower than the mouth of the well sufficient to allow the escape of the water; sufficient rainfall at the exposed edge of the water-bearing bed to completely saturate the whole bed. The water-bearing stratum may be either porous or fissured.

Uncertainties in boring for artesian water due to the variations in the character of the water-bearing bed, variations in the overlying bed, and to possible faults that permit the escape of the water or prevent its reaching the well. The general principles are simple, but the problems are often complex.

Special cases require special study.

Artesian waters are seldom obtained from crystalline rocks, but sometimes water is obtained from the joints in them, as at York, Maine.[7]

Artesian water is not confined to rocks of any particular age. In California they are more abundant in the later formations.[8]

[6]G. K. Gilbert.—The underground water of the Arkansas valley in eastern Colorado. Seventeenth ann. rep. U. S. Geological Survey, pt. II, 557-601. Washington, 1896.

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R. T. Hill.—On the occurrence of artesian and other underground waters in Texas, eastern New Mexico, and Indian Territory, west of the 97th meridian. Senate Ex. document 41, 48-166.

[7]G. O. Smith.—The artesian waters in crystalline rocks. Science, New Series XXI, 224-225. New York, 1905.

[8]W. C. Mendenhall.—Preliminary report on the ground waters of San Joaquin Valley, California. Water supply paper no. 222. U. S. Geological Survey, Washington, 1908.

Fig. 125.—Section showing how a horizontal well may obtain water from vertical beds.

Size and strength of the flow of artesian wells depends upon:[9]

1. Distance of discharge from outcrop.
2. Porosity of the water-bearing beds.
3. Character of the confining beds.
4. Character of the country between the outcrop of the water-bearing bed and the well.
5. Height of the outcrop of the water bed above the mouth of the well.

Artesian water important for:

City water supplies.

Domestic purposes.

Irrigation.

Limits of artesian water for irrigation.

Medicinal purposes.

Examples of artesian well regions.

Impossibility of locating water and minerals by the use of the divining rod.[10]

Protection of water sources.

[9]M. L. Fuller.—Summary of the controlling factors of artesian flows. Bul. 319, U. S. Geological Survey. Washington, 1908.

King and Slichter.—(On the flow of water from artesian wells.) 19th an. rep. U. S. Geological Survey, pt. II, 59-384. Washington, 1899.

[10]M. E. Wadsworth.—The mechanical action of the divining rod. American Geologist, XXI, 72. Minneapolis, 1898.

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